Picture 1. Lake SHERWOOD, 18 AUGUST 2021

A FISH SURVEY

OF LAKE SHERWOOD, 2021

Study performed: 18-19 August 2021
Final Report submitted: 13 April 2022

Prepared by: David J. Jude, Ph.D.,
Limnologist, Fishery Biologist

FRESHWATER PHYSICIANS, INC

5293 DANIEL, BRIGHTON MI 48114 P: 810-227-6623

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INTRODUCTION

Freshwater Physicians was asked to conduct a water quality and zooplankton survey of Sherwood Lake, which we executed on 16 September 2020 with assistance and guidance from Dan Devine (see Freshwater Physicians 2021 for report). Subsequently, we conducted a fish survey during 2021, which is the subject of this report. We also collected some dissolved oxygen data to complement our results.

From Fusilier (2010): Lake Sherwood is a 258-acre, moderately hard water to hard water impoundment created about 1956-57 when a dam was constructed across the outlet from Teeple Lake (the Wildwood River). The lake consists of a 144.8-acre main body, plus an 18.7-acre series of canals north of Commerce Road (Wildwood Canals) and another 94.5-acre group of canals east of the main body of the lake (East canals). The lake is in sections 6, 7, 8, Commerce Township (T2N R8E), Oakland Co., MI. The lake has five islands totaling about 2 acres, so the area of the water surface is 256 acres.

There are at least three invasive species in the lake: Eurasian milfoil, starry stonewort, and zebra mussels. Schneider (2003) noted that Eurasian milfoil covered 90% of the surface area of the lake during 2003. The macrophytes are currently being treated with herbicides, while the zebra mussels seem to have declined to low abundances. Eurasian milfoil covers a much smaller amount of surface area, but during our study extensive and expansive blue-green algae were observed in the lake and it appeared that these blooms plagued Sherwood Lake during the summer season.

There are at least four major reports on Sherwood Lake done in the past. Freshwater Physicians (2012) did an extensive limnological study during summer 2011, Fusilier (2010) has extensive data covering 1994-2010 data (limnological, macrophyte, sediment data), and there are two prior fish studies (Merna 1981 and Schneider 2003). These data sets were helpful in providing conclusions on long term changes in various parameters and will provide a rich background and bench marks from which to assess any ecological changes to the lake in the future.

Our approach in this report was to document the status of the various components of the study, discuss previous datasets for each parameter, and present the current condition of the lake and means of improvement.

HISTORY

The Sherwood Lake impoundment was created about 1956-57 when a dam was constructed across the stream (Wildwood River) that originates far upstream at Teeple Lake. There is a supplemental well (currently inoperable) on the north end that was used for lake augmentation when water levels are low. The lake is also drawn down each fall around 18 in to promote sediment drying, macrophyte control, and allows residents to clean up beaches. Some dredging activities were ongoing in the past in the Wildwood River which flows into Sherwood Lake. There is a history of algae and macrophyte control of the extensive plants that occupy the lake. There is a warm-water fishery in the lake and walleyes have been stocked in the past to provide another predator for sport fishers.

METHODS

Our study involves physical, chemical, and biological measurements and observations by professional aquatic biologists who have conducted lake management studies since 1972; we incorporated in 1974. We use specialized samplers and equipment designed to thoroughly examine all components of an aquatic ecosystem. Shallow water, deep water, sediments, animal and plant life as well as inlet and outlet streams are intensively sampled and analyzed at several key stations (sites on the lake). Some samples are analyzed in the field, while the balance is transported to our laboratory for measurements and/or identification of organisms found in samples.

After the field study, we compile, analyze, summarize, and interpret data. We utilize a comprehensive library of limnological studies and review all the latest management practices in constructing a management plan. All methods used are standard limnological procedures, and most chemical analyses are according to Standard Methods for the Examination of Water and Wastewater. Water analyses were performed by Grand Valley State University.

<u>STATION LOCATIONS</u>

During any study we choose several places (stations) where we do our sampling for each of the desired parameters. We strive to have a station in any unusual or important place, such as inlet and outlet streams, as well as in representative areas in the lake proper. One of these areas is always the deepest part of the lake. Here we check on the degree of thermal and chemical stratification, which is extremely important in characterizing the stage of eutrophication (nutrient enrichment), invertebrates present, and possible threats to fish due to production of toxic substances due to decomposition of bottom sediments. The number and location of these stations for this study are noted in that section.

PHYSICAL PARAMETERS

Depth

Depth is measured in several areas with a sonic depth finder. We sometimes run transects across a lake and record the depths if there are no data about the depths of the lakes. These soundings can then be superimposed on a map of the lake and a contour map constructed to provide some information on the current depths of the lake.

Acreage

Acreage figures, when desired, are derived from maps, by triangulation, and/or estimation. The percentage of lake surface area in shallow water (less than 10 feet) is an important factor. This zone (known as the littoral zone) is where light can penetrate with enough intensity to support rooted aquatic plants. Natural lakes usually have littoral zones around their perimeters. Man-made lakes and some reservoirs often have extensive areas of littoral zone.

Hydrographic Map

A map of the depth contours of the lake was used to show where we sampled, important areas, tributaries, and depth contours. This map will assist us in identifying where past stations were sampled in prior studies and in making assessments of the lake.

Sediments

Bottom accumulations give good histories of the lake. The depth, degree of compaction, and actual makeup of the sediments reveal much about the past. An Ekman grab or Petite Ponar sampler is used to sample bottom sediments for examination. It is lowered to the bottom, tripped with a weight, and it "grabs" a sample of the bottom. Artificial lakes often fill in more rapidly than natural lakes because disruption of natural drainage systems occurs when these lakes are built. Sediments are either organic (remains of plants and animals produced in the lake or washed in) or inorganic (non-living materials from wave erosion or erosion and run-off from the watershed).

Light Penetration

The clarity of the water in a lake determines how far sunlight can penetrate. This in turn has a basic relationship to the production of living phytoplankton (minute plants called algae), which are basic producers in the lake, and the foundation of the food chain. We measure light penetration with a small circular black and white Secchi disc attached to a calibrated line. The depth at which this disc just disappears (amount of water transparency) will vary between lakes and in the same lake during different seasons, depending on degree of water clarity. This reference depth can be checked periodically and can reflect the presence of plankton blooms and turbidity caused by urban run-off, etc. A regular monitoring program can provide an annual documentation of water clarity changes and a historical record of changes in the algal productivity in the lake that may be related to development, nutrient inputs, or other insults to the lake. Secchi disk measurements also dictate what trophic state: eutrophic, mesotrophic, or oligotrophic a lake has.

The criteria for this Secchi disk measurement are as follows: <7.5 ft = eutrophic, 7.5-15 ft = mesotrophic, and >15 ft = oligotrophic.

Temperature

This is a physical parameter but will be discussed in the chemistry section with dissolved oxygen. Thermal stratification is a critical process in lakes which helps control the production of algae, generation of various substances from the bottom, and dissolved oxygen depletion rates.

CHEMICAL PARAMETERS

Water chemistry parameters are extremely useful measurements and can reveal considerable information about the type of lake and how nutrients are fluxing through the system. They are important in classifying lakes and can give valuable information about the kind of organisms that can be expected to exist under a certain chemical regime. All chemical parameters are a measure of a certain ion or ion complex in water. The most important elements--carbon (C), hydrogen (H), and oxygen (O) are the basic units that comprise all life, so their importance is readily obvious. Other elements like phosphorus (P) and nitrogen (N) are extremely important because they are significant links in proteins and RNA/DNA chains. Since the latter two (P and N) are very important plant nutrients, and since phosphorus has been shown to be critical and often a limiting nutrient in some systems, great attention is given to these two variables. Other micronutrients such as boron, silicon, sulfur, and vitamins can also be limiting under special circumstances. However, in most cases, phosphorus turns out to be the most important nutrient.

Temperature Stratification

Temperature governs the rate of biological processes. A series of temperature measurements from the surface to the bottom in a lake (temperature profile) is very useful in detecting stratification patterns. Stratification in early summer develops because the warm sun heats the surface layers of a lake. This water becomes less dense due to its heating, and "floats" on the colder, denser waters below. Three layers of water are thus set up. The surface warm waters are called the epilimnion, the middle zone of rapid transition in temperatures is called the thermocline, and the cold bottom waters, usually around 39 F (temperature of maximum density), are termed the hypolimnion. As summer progresses, the lowest cold layer of water (hypolimnion) becomes more and more isolated from the upper layers because it is colder and denser than surface waters (see Fig. 1 for documentation of this process over the seasons).

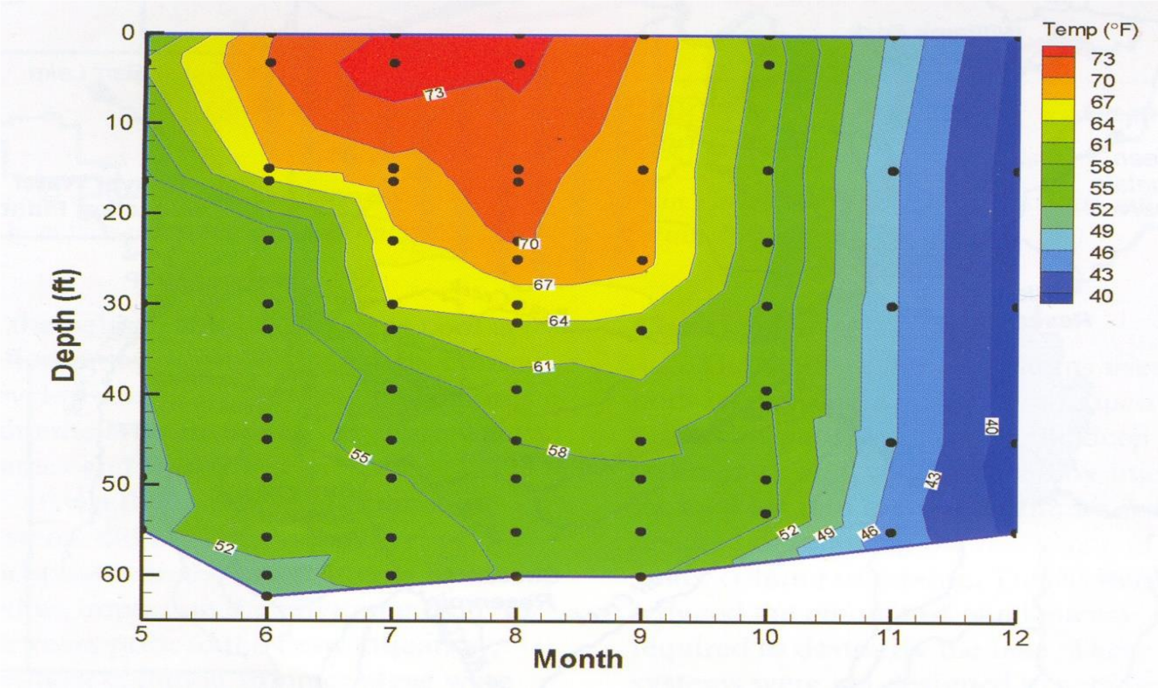

Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red yellow and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during summer months. Adapted from NALMS.

When cooler weather returns in the fall, the warm upper waters (epilimnion) cool to about 39 F, and because water at this temperature is densest (heaviest), it begins to sink slowly to the bottom. This causes the lake to "turnover" or mix (blue part on right of Fig. 1), and the temperature becomes a uniform 39 F top to bottom. Other chemical variables, such as dissolved oxygen, ammonia, etc. are also uniformly distributed throughout the lake.

As winter approaches, surface water cools even more. Because water is most dense at 39 F, the deep portions of the lake "fill" with this "heavy water". Water colder than 39 F is lighter and floats on the denser water below, until it freezes at 32 F and seals the lake. During winter decomposition on the bottom can warm bottom temperatures slightly.

In spring when the ice melts and surface water warms from 32 to 39 F, seasonal winds will mix the lake again (spring overturn), thus completing the cycle. This represents a typical cycle, and many variations can exist, depending on the lake shape, size, depth, and location. Summer stratification is usually the most critical period in the cycle, since the hypolimnion may go anoxic (without oxygen--discussed next). We always try to schedule our sampling during this period of the year. Another critical time exists during late winter as oxygen can be depleted from the entire water column in certain lakes under conditions of prolonged snow cover.

Dissolved Oxygen

This dissolved gas is one of the most significant chemical substances in natural waters. It regulates the activity of the living aquatic community and serves as an indicator of lake conditions. Dissolved oxygen is measured using an YSI, dissolved oxygen-temperature meter or the Winkler method with the azide modification. Fixed samples are titrated with PAO (phenol arsene oxide) and results are expressed in mg/L (ppm) of oxygen, which can range normally from 0 to about 14 mg/L. Water samples for this and all other chemical determinations are collected using a device called a Kemmerer water sampler, which can be lowered to any desired depth and like the Ekman grab sampler, tripped using a messenger (weight) on a calibrated line. The messenger causes the cylinder to seal and the desired water sample is then removed after the Kemmerer is brought to the surface. Most oxygen in water is the result of the photosynthetic activities of plants, the algae and aquatic macrophytes. Some enters water through diffusion from air. Animals use this oxygen while giving off carbon dioxide during respiration. The interrelationships between these two communities determine the amount of productivity that occurs and the degree of eutrophication (lake aging) that exists.

A series of dissolved oxygen determinations can tell us a great deal about a lake, especially in summer. In many lakes in this area of Michigan, a summer stratification or stagnation period occurs (See previous thermal stratification discussion). This layering causes isolation of three water masses because of temperature-density relationships already discussed (see Fig. 2 for demonstration of this process).

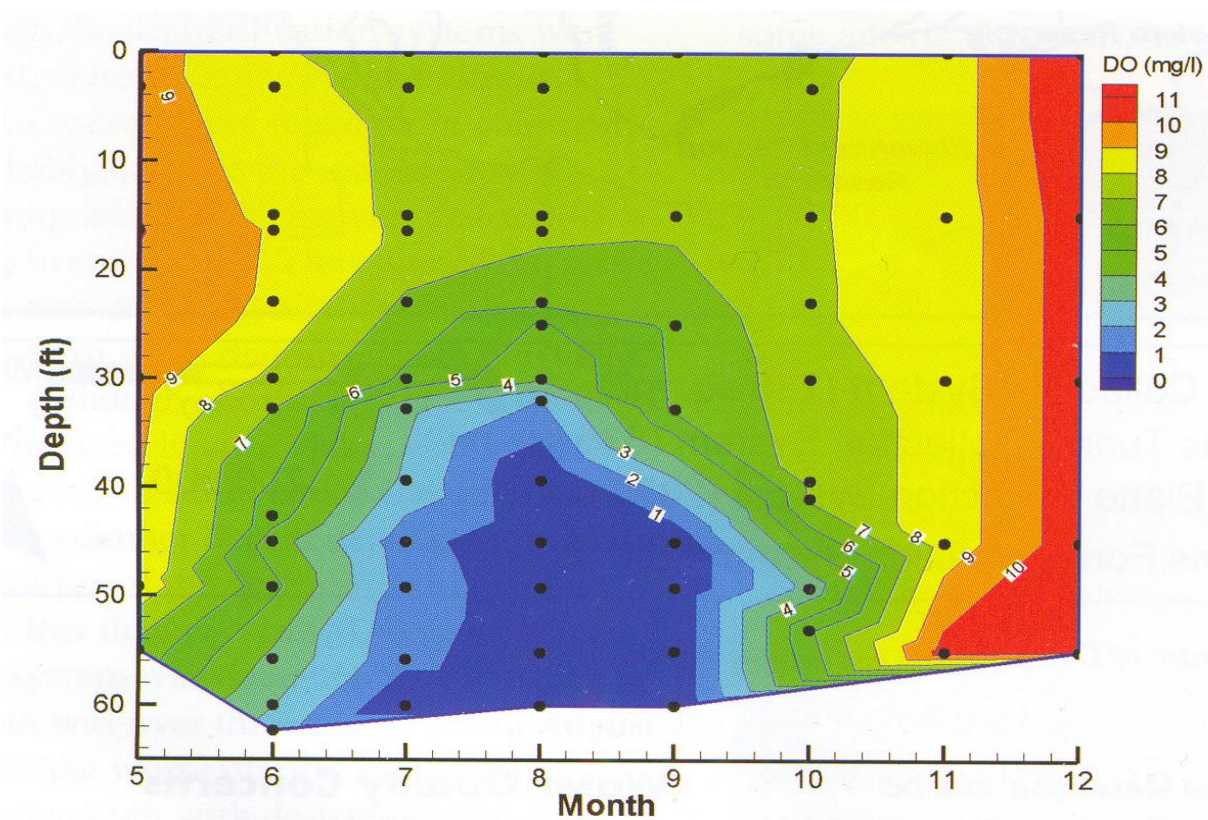

Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when the dissolved oxygen is the same from top to bottom. Adapted from NALMS.

In the spring turnover period dissolved oxygen concentrations are at saturation values from top to bottom (see red area which is the same in the spring – Fig. 2). However, in these lakes by July or August some or all the dissolved oxygen in the bottom layer is lost (consumed by bacteria) to the decomposition process occurring in the bottom sediments (blue area in Fig. 2). The richer the lake, the more sediment produced, and the more oxygen consumed. Since there is no way for oxygen to get down to these layers (there is not enough light for algae to photosynthesize), the hypolimnion becomes devoid of oxygen in rich lakes. In non-fertile (Oligotrophic) lakes there is very little decomposition, and therefore little or no dissolved oxygen depletion. Lack of oxygen in the lower waters (hypolimnion) prevents fish from living there and changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic). In eutrophic lakes, the surface waters can be too warm for cool-water fish, while the optimal cool waters in the hypolimnion are devoid of oxygen, squeezing fish in a thin layer in the middle. Fish like northern pike can be stressed, while more sensitive species, such as lake herring can perish when the dissolved oxygen levels decline too much (see Fig. 3).

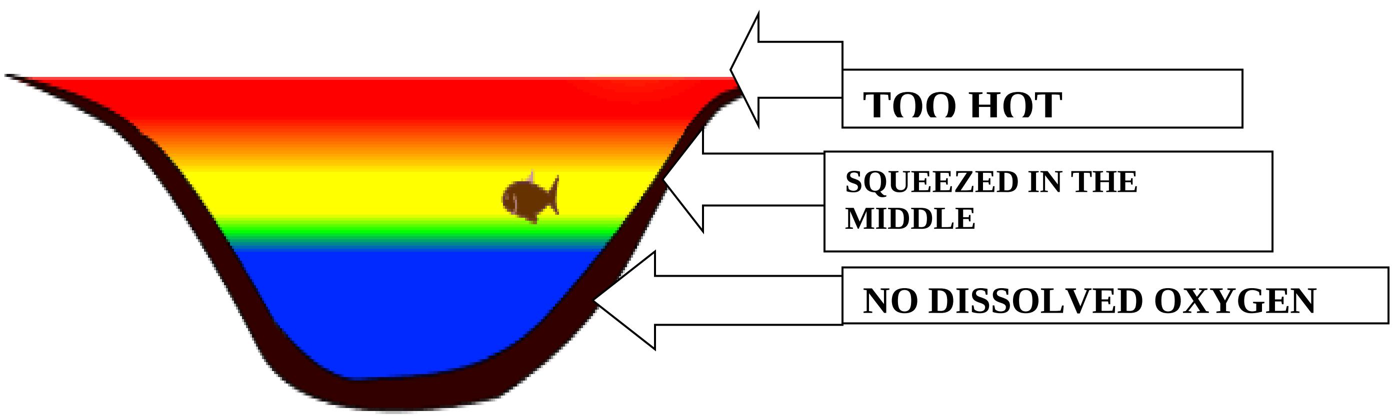

Figure 3. Depiction of the dissolved oxygen concentrations in a stratified lake during summer, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, but has no or very low dissolved oxygen present. Cool water fishes, such as northern pike and walleyes are “squeezed” between these two layers and undergo thermal stress during long periods of summer stratification.

Stratification does not occur in all lakes. Shallow lakes are often well mixed throughout the year because of wind action. Some lakes or reservoirs have large flow-through so stratification never gets established.

Stratified lakes will mix in the fall because of cooler weather, and the dissolved oxygen content in the entire water column will be replenished. During winter the oxygen may again be depleted near the bottom by decomposition processes. As noted previously, winterkill of fish results when this condition is caused by extensive snows and a long period of ice cover when little sunlight can penetrate the lake water. Thus, no oxygen can be produced, and if the lake is severely eutrophic, so much decomposition occurs that all the dissolved oxygen in the lake is depleted.

In spring, with the melting of ice, oxygen is again injected into the hypolimnion during this mixing or "turnover" period. Summer again repeats the process of stratification and bottom depletion of dissolved oxygen.

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 24-hour cycle. During the day in summer, plants photosynthesize and produce oxygen, while at night they join the animals in respiring (creating CO2) and using up oxygen. This creates a diel cycle of high dissolved oxygen levels during the day and low levels at night. These dissolved oxygen sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

pH

The pH of most lakes in this area ranges from about 6 to 9. The pH value (measure of the acid or alkaline nature of water) is governed by the concentration of H (hydrogen) ions which are affected by the carbonate-bicarbonate buffer system, and the dissociation of carbonic acid (H2CO3) into H + ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO2 from the carbonate-bicarbonate system. The pH will rise as a result. During evening hours, the pH will drop due to respiratory demands (production of carbon dioxide, which is acidic). This cycle is like the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO2 during the day in photosynthesis there is a drop in CO2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO2), thus causing a rise in CO2 concentration and a concomitant decrease in pH toward a more acidic condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution, which would cause deviations from expected values. In the field, pH is measured with color comparators or a portable pH/conductivity meter and in the laboratory with a pH meter.

Chlorides

Chlorides are unique in that they are not affected by physical or biological processes and accumulate in a lake, giving a history of past inputs of this substance. Chlorides (Cl-) are transported into lakes from septic tank effluents and urban run-off from road salting and other sources. Chlorides are detected by titration using mercuric nitrate and an indicator. Results are expressed as mg/L as chloride. The effluent from septic tanks is high in chlorides. Dwellings around a lake having septic tanks contribute to the chloride content of the lake. Depending upon flow-through, chlorides may accumulate in concentrations considerably higher than in natural ground water. Likewise, urban run-off can transport chlorides from road salting operations and bring in nutrients. The chloride "tag" is a simple way to detect possible nutrient additions and septic tank contamination. Ground water in this area averages 10-20 mg/L chlorides. Values above this are indicative of possible pollution.

Phosphorus

This element, as noted, is an important plant nutrient, which in most aquatic situations is the limiting factor in plant growth. Thus, if this nutrient can be controlled, many of the undesirable side effects of eutrophication (dense macrophyte growth and algae blooms) can be avoided. The addition of small amounts of phosphorus (P) can trigger these massive plant growths. Usually the other necessary elements (carbon, nitrogen, light, trace elements, etc.) are present in quantities sufficient to allow these excessive growths. Phosphorus usually is limiting (occasionally carbon or nitrogen may be limiting). Two forms of phosphorus are usually measured. Total phosphorus is the total amount of P in the sample expressed as mg/L or ppm as P, and soluble P or Ortho P is that phosphorus which is dissolved in the water and "available" to plants for uptake and growth. Both are valuable parameters useful in judging eutrophication problems.

Nitrogen

There are various forms of the plant nutrient nitrogen, which are measured in the laboratory using complicated methods. The most reduced form of nitrogen, ammonia (NH3), is usually formed in the sediments in the absence of dissolved oxygen and from the breakdown of proteins (organic matter). Thus, high concentrations are sometimes found on or near the bottom under stratified, anoxic conditions. Ammonia is reported as mg/L as N and is toxic in high concentrations to fish and other sensitive invertebrates, particularly under high pHs. With turnover in the spring most ammonia is converted to nitrates (NO3=) when exposed to the oxidizing effects of oxygen. Nitrite (NO2-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured. Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. Nitrates, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about succession of algae species, which usually proceeds from diatoms, to green algae to blue-green algae. Blue-green algae (an undesirable species) can fix their own nitrogen (some members) and thus out-compete more desirable forms, when phosphorus becomes scarce in late summer.

BIOLOGICAL PARAMETERS

Algae

The algae are a heterogeneous group of plants, which possess chlorophyll by which photosynthesis, the production of organic matter and oxygen using sunlight and carbon dioxide, occurs. They are the fundamental part of the food chain leading to fish in most aquatic environments.

There are several different phyla, including the undesirable blue-green algae, which contain many of the forms which cause serious problems in highly eutrophic lakes. These algae can fix their own nitrogen (a few forms cannot) and they usually have gas-filled vacuoles which allow them to float on the surface of the water. There is usually a seasonal succession of species, which occurs depending on the dominant members of the algal population and the environmental changes, which occur.

This usual seasonal succession starts with diatoms (brown algae) in the spring and after the supply of silica, used to construct their outside shells (frustules), is exhausted, green algae take over. When nitrogen is depleted, blue-green algae can fix their own and become dominant in late summer.

The types of algae found in a lake serve as good indicators of the water quality of the lake. The algae are usually microscopic, free-floating single and multicellular organisms, which are responsible many times for the green or brownish color of water in which they are blooming. The filamentous forms, such as *Spirogyra* and *Cladophora* are usually associated with aquatic macrophytes, but often occur in huge mats by themselves. The last type, *Chara*, a green alga, looks like an aquatic macrophytes and grows on the bottom in the littoral zone, sometimes in massive beds. Starry stonewort *Nitellopsis obtusa* is an exotic invasive alga that looks like *Chara*. It is important to identify it in lakes since it can dominate large areas of the lake and damage spawning sites and prevent boat access and fishing in areas where it is present. It is spread from lake to lake on boats and other equipment from infected lake. Hence, it is important to prevent its spread by having good education of lake residents and signage at boat launch sites to prevent its spread. It is important to understand the different plant forms and how they interact, since plants and algae compete for nutrients present and can shade one another out depending on which has the competitive advantage. This knowledge is important in controlling them and formulating sensible management plans.

Macrophytes

The aquatic plants (emergent and submersed), which are common in most aquatic environments, are the other type of primary producer in the aquatic ecosystem. They only grow in the euphotic zone, which is usually the inshore littoral zone up to 6 ft., but in some lakes with good water clarity and with the introduced Eurasian water-milfoil (*Myriophyllum spicatum)*; milfoil has been observed in much deeper water. Plants are very important as habitat for insects, zooplankton, and fish, as well as their ability to produce oxygen. Plants have a seasonal growth pattern wherein over wintering roots or seeds germinate in the spring. Most growth occurs during early summer. Again, plants respond to high levels of nutrients by growing in huge beds. They can extract required nutrients both from the water and the sediment. Phosphorus is a critical nutrient for them. The aquatic plants and algae are closely related, so that any control of one must be examined considering what the other forms will do in response to the newly released nutrients and lack of competition. For example, killing all macrophytes may result in massive algae blooms, which are even more difficult to control. Aquatic plants are important spawning substrate, habitat for fish, nursery areas for small fish, they produce aquatic insects, and they are important for stabilizing sediments. They can slow down currents and prevent re suspension of sediments, which contain nutrients, which can be released into the upper water column and fuel algal blooms.

Zooplankton

This group of organisms is common in most bodies of water, particularly in lakes and ponds. They are very small creatures, usually less than 1/8 inch, and usually live in the water column where they eat detritus and algae. Some prey on other forms. This group is seldom seen in ponds or lakes by the casual observer of wildlife but is a very important link in the food web leading from the algae to fish. They are usually partially transparent organisms, which have limited ability to move against currents and wave action but are sometimes considered part of the 'plankton' because they have such little control over their movements, being dependent on wind-induced or other currents for transport.

Zooplankton is important since they are indicators for biologists for three reasons. First, the kind and number present can be used to predict what type of lake they live in as well as information about its stage of eutrophication. Second, they are very important food sources for fish (especially newly hatched and young of the year fish), and third, they can be used to detect the effects of pollution or chemical insult if certain forms expected to be present are not. These data can be added to other such data on a lake and the total picture can then lead to the correct conclusions about what has occurred in a body of water.

Zooplankton is collected by towing a No. 10 plankton net (153 microns) through the water and the resulting sample is preserved with 10% formaldehyde and then examined microscopically in the laboratory. Qualitative estimates of abundance are usually given.

Fish

The top carnivores in most aquatic ecosystems, excluding man, are the fish. They are integrators of a vast number and variety of ever-changing conditions in a body of water. They, unlike the zooplankton and benthos, which can reflect short-term changes, are indicative of the long-range, cumulative influences of the lake or stream on their behavior and growth. The kind of fish, salmon or sunfish, can tell us much about how oligotrophic (low productivity) or eutrophic (high productivity) a lake is. We collect fish with seines, gill nets, trap nets, and from lucky fishermen on the lake. Most fish are weighed, measured, sexed, and their stomach contents removed and identified. Fish are aged using scales, and breeding condition is observed and recorded. The catches from our nets and age information on the fish will tell us how your length-at-age data compare with state averages and whether fish growth is good. Another problem, "stunting", can be detected using these sources of information.

Stomach contents of fish document whether good sources of food are present and help confirm age and growth conclusions. Imbalances in predator-prey relationships are a closely related problem, which we can usually ascertain by examining the data and through discussions with local fishermen. From studying the water chemistry data and supportive biological data, we can make recommendations, such as habitat improvement, stocking of more predators, and chemical renovation. We can also predict for example, the effects of destroying macrophytes through chemical control. All elements of the ecosystem are intimately interrelated and must be examined to predict or solve problems in a lake or help us explain perplexing problems discovered in the lake ecosystem.

RESULTS

WATERSHED

Sherwood Lake is in Oakland County in Commerce Township, Mi and is about 256 acres. The watershed not including the lake is 6,974 acres (see Fig. 5). The drainage area, which includes the lake and the watershed, is 7,232 acres; the watershed to lake ratio is 27 to 1, which is high for a Michigan inland lake but normal for a lake created by damming a stream (Fusilier 2010). There are two main inlets: Wildwood River and Cranberry Lake inlet, both entering the lake from the north (Fig. 4, 5, 6). The outlet is on the southwest corner of the lake. Water from the outlet flows to the Huron River east of Milford. The Huron River flows into Lake Erie at Monroe, MI. The lake has 65,254 ft of shoreline not including the shorelines of the islands. Elevation is 925 ft above sea level. It has two deep basins around 20 ft. There are areas where macrophytes are common to abundant, including Eurasian milfoil in several areas as well as starry stonewort. These plants have been treated with herbicides in recent years.

The local riparian zone, as we noted above, is important, especially that band right at the lake. There are ca. 630 residences in the area around the lake; 320 are riparians. Residents in the watershed need to plant green belts to retard runoff into the lake among other recommendations (see Appendix 1).

STATION LOCATION

Sherwood Lake is a 256-acre, shallow, eutrophic lake with two basins located in Oakland County, MI. The overall view of Sherwood Lake is provided by a Google map (Fig. 4) and shows the complex nature of the lake with its many arteries and channels and there is an inlet stream on the north side. Also, there are islands and the lake is well developed with many houses (320 riparians), paved roads, and other developments in the watershed. Water quality was measured at stations 1-7 during summer 2020 (Freshwater Physicians 2021). These stations were established by Fusilier (2010) and include station 7 in the incoming inlet stream (Wildwood River) on the north end which eventually flows out of Teeple Lake (see Fig. 5 for the watershed which is large, Fig. 6 and Table 1 for station locations, and Fig. 7 for a contour map).

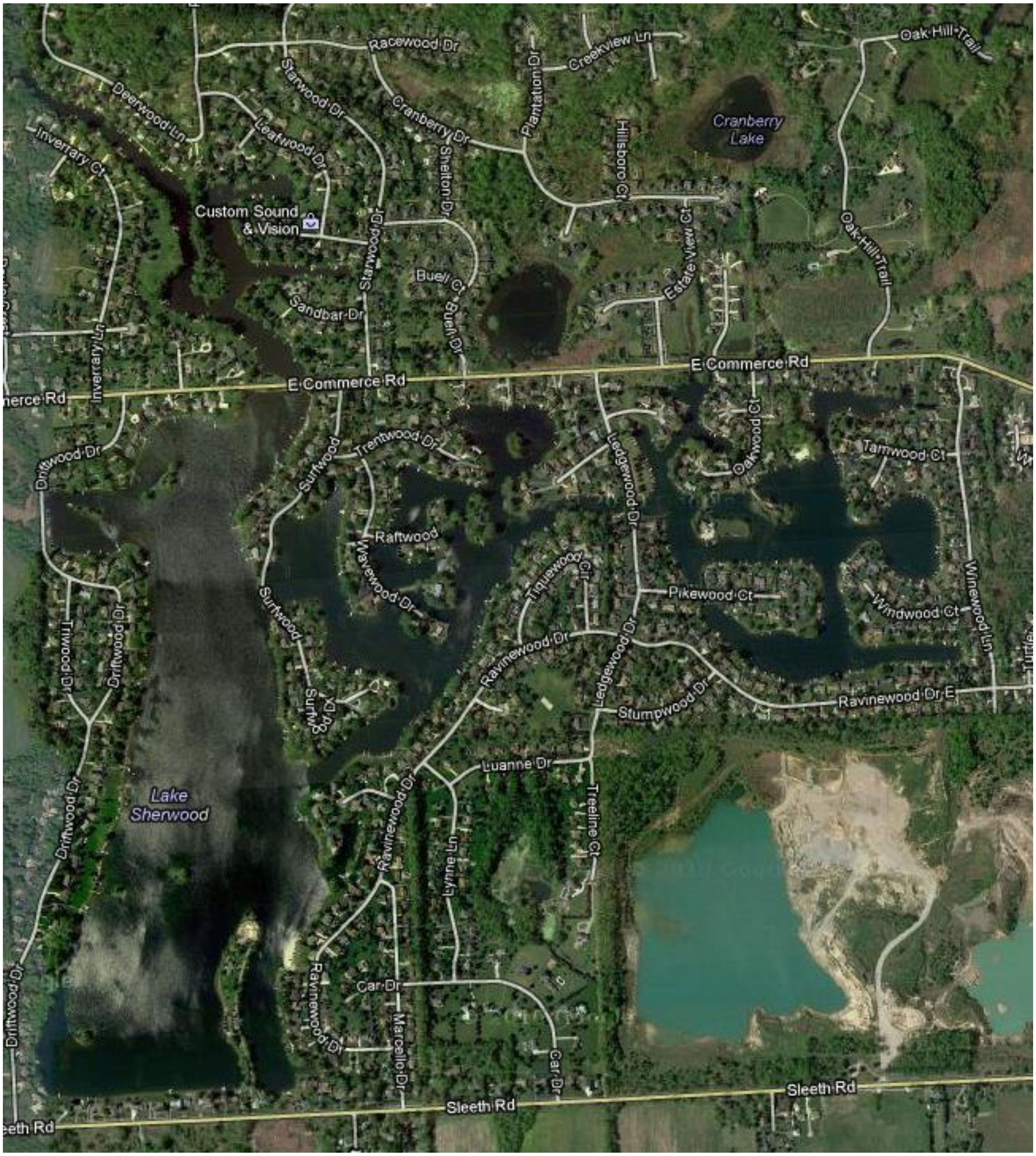

Figure 4. Google map of Sherwood Lake showing the extensive development around most of the lake, the diverse channels and canals, and the inlets and outlet.

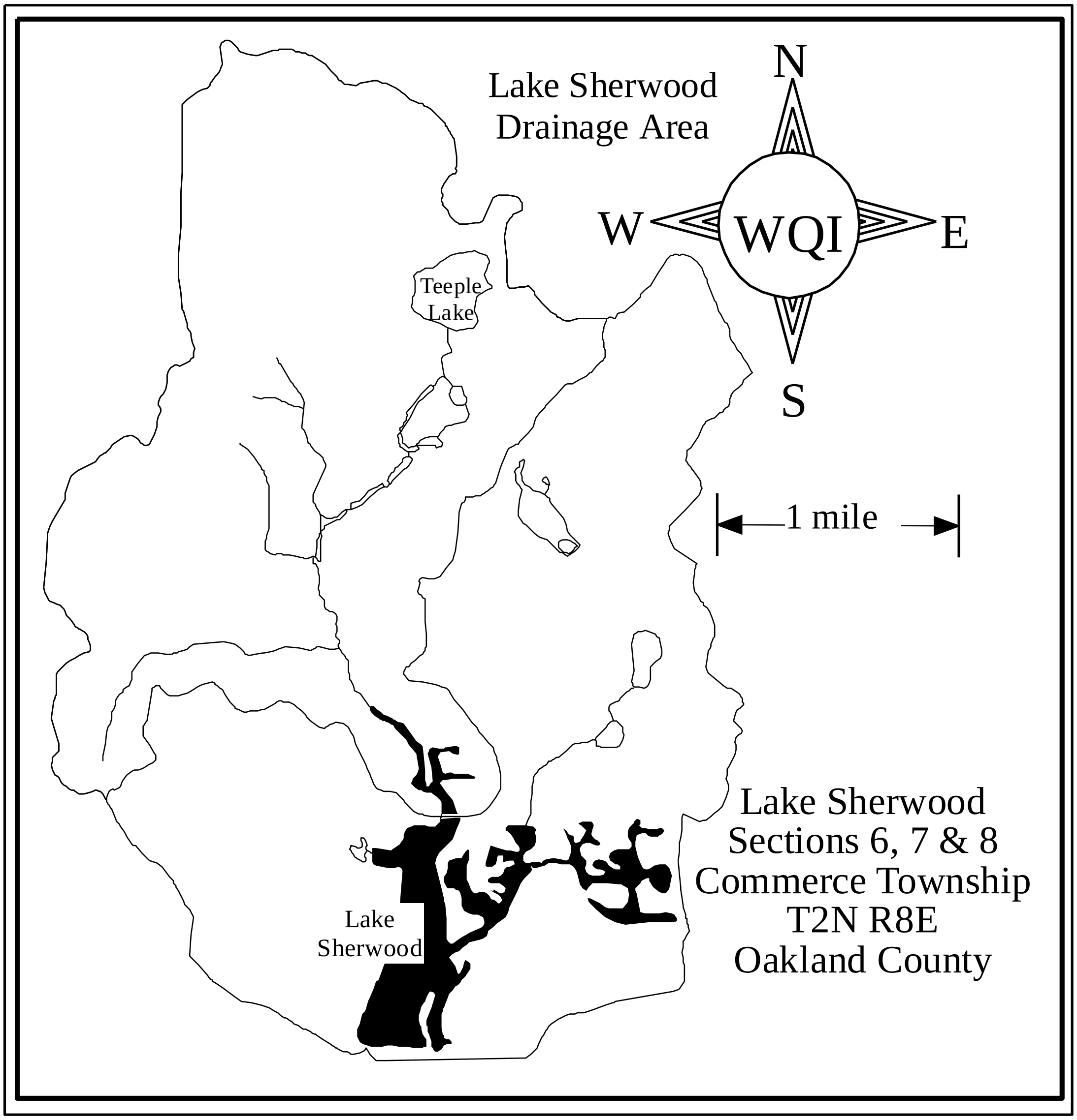

Figure 5. Map of Sherwood Lake showing the watershed of the lake. Adapted from a map provided by Fusilier (2010).

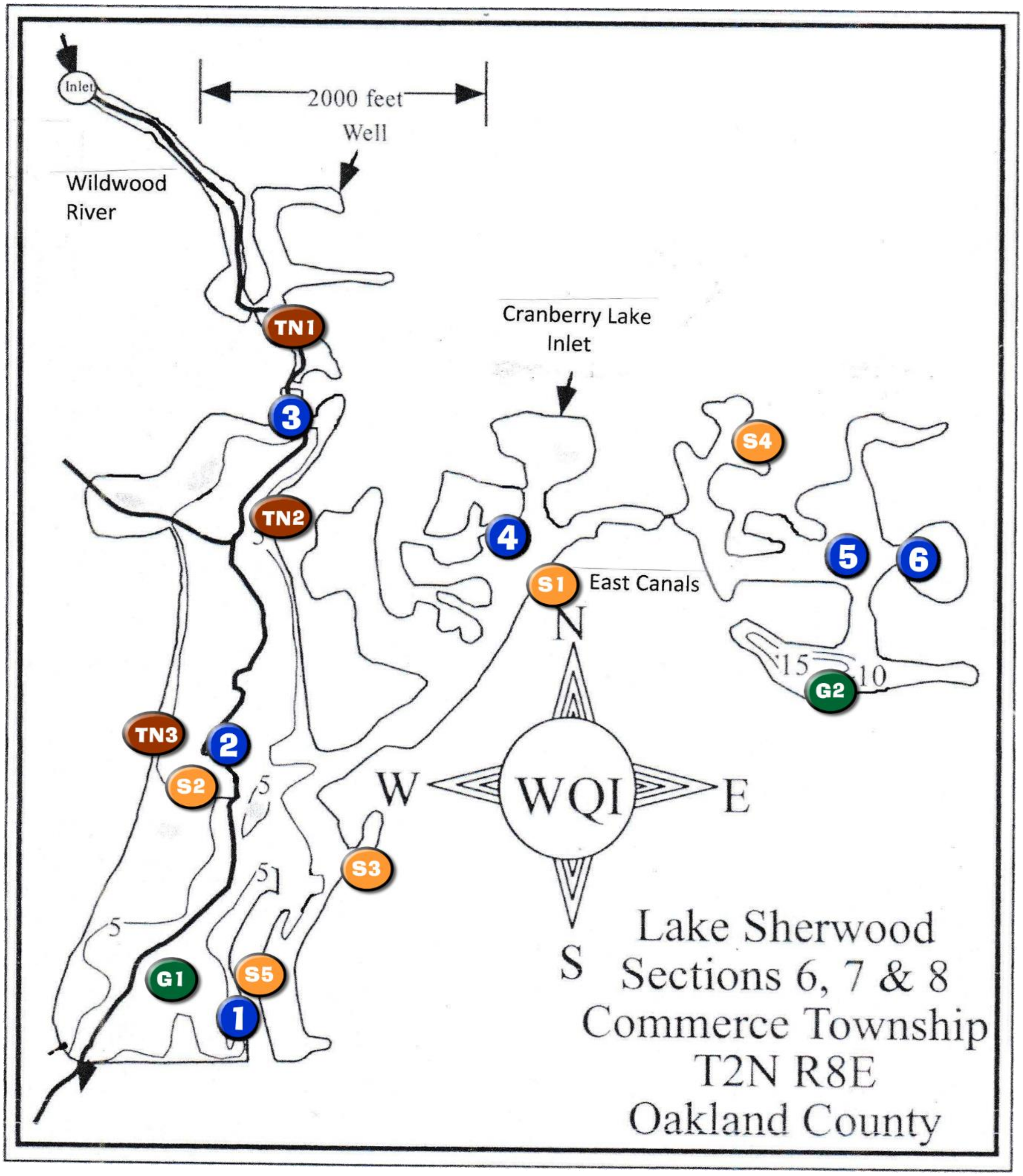

Figure 6. Map of Sherwood Lake showing the water quality stations 1 – 7, inlet stream (Wildwood River which flows out of Teeple Lake some distance away), inlet from Cranberry Lake, the islands, and sites where seining (S), gillnetting (G), and trap nets (TN) were deployed. Adapted from a map provided by Fusilier (2010).

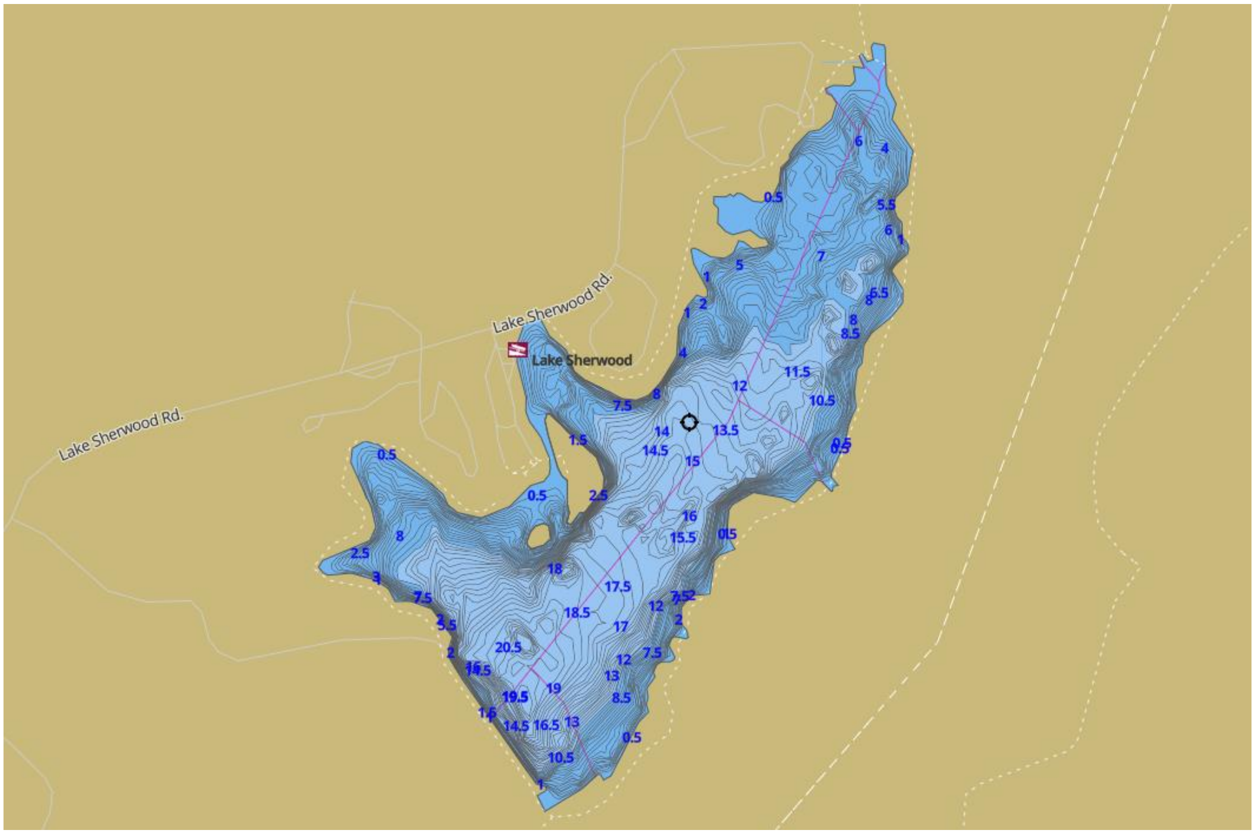

Figure 7. Map of Sherwood Lake showing the depth contours and deep holes.

Table 1. Stations on Lake Sherwood sampled for water quality parameters. Provided is a description and GPS locations. See Fig. 4-7 for station locations and Google maps.

Station	Station Description
<u>Water Quality Sites</u>	
1	Master station deepest - 19.8 ft; near dam; S end of lake GPS: N 42 34.975 W-83 33.028
2	Mid - lake; 8.5 ft deep GPS: N42 35.248 W-83 33.149
3	N end of lake; S of road bridge; 7 ft GPS: N 42 35.753 W-83 32.967
4	Middle of first section of Wildwood Canal; 14.9 ft GPS: N 42 35.566 W-83 32.575

5 Center of second section of Wildwood Canal; 10.2 ft
GPS: N42 35.600 W-83 32.065

6 East-most station of Wildwood Canal; 10.6 ft
GPS:N 42 35.597 W-83 31.912

7 N-most station on lake; close to inlet stream (Wildwood River)
GPS:N 42 35.870 W-83 33.013

Fish Sampling Sites

S1 3370 Tiquewood Road
GPS: N24 35.566 W-83 32.542

S2 Off island
GPS: N42 35.209 W-8333.068

S3 Eastern part of lake
GPS: N42 35.111 W-83 32.912

S4 Northeastern part of lake; canal area
GPS: N42 35.607 W-83 32.018

S5 Southern end of lake near dam
GPS:N42 35,038 W-83 33.008

TN1 Northern end of lake near bridge
GPS: N42 35.763 W-83 32.937

TN2 Northern end of lake
GPS: N42 35.648 W-83 33.084

TN3 Mid lake near island
GPS:N42 25.123 W-83 33.219

G1 South end of lake near dam: 11-18 FT
GPS: 42 34.967 W-83 33.221

G2 Eastern canals deep area: 9-18 FT
GPS: N42 35.189 W-83 33.184

PHYSICAL PARAMETERS

Depth

Sherwood Lake is a shallow lake with one deep spot (station 1 - >20 ft) (Fig. 6). The mean depth of the main lake is about 5.4 ft and the water volume is 779 acre feet (Fusilier 2010). The main lake flushes about once every 47 days. The mean depth of the north (Wildwood) canal is about 2.5 ft and the volume is 48 acre-feet. The north canal flushes about once a week. The mean depth of the east canal system is also about 2.5 ft and the volume is 235 acre-ft. This canal system flushes about once every 63 days.

Acreage

Sherwood Lake is 256 acres (see Fig. 5 map). The lake is extensively developed in the watershed (see Fig. 4) with 320 houses ringing the lake. Because it is so circuitous, it has room for many houses, where a lake more roundish (measurement called Shoreline Development) would have many fewer houses and thus less impact on the lake.

Sediments

We did not sample the bottom sediments of Sherwood Lake, but expect them to be muck, flocculent in the deep areas, and have deep accumulations in the deep basins. However, Fusilier (2010) measured samples from various areas in the lake during 1994. He found that the % mineral content varied from 76 to 92, which indicates a buildup of organic material, which was not expected, since the lake is relatively young having been flooded during 1956. The major content of the sediments is clay, probably derived from home building and runoff, input from roads, or the bottom soils at flooding were mostly clay.

Light Penetration

We include the Secchi Disk data from the previous report (Freshwater Physicians 2020) and compare it with 2021 data to have these data available for the 2021 study.

1980-2010: Fusilier (2010). An examination of the prior data summarized in Fusilier (2010) from 1980 to 2010 (an impressive Secchi disk record), showed Secchi disk trends generally decreased (10-12 ft to 4.8 ft) from 1980 to 2000, then during 2005 there was a dramatic increase in average values from 2002 to 2005-2006, when the mean value increased to 14.8 ft. Could this be due to zebra mussels? However, after 2006 values decreased to 8.3 ft during 2010 and the average we calculated for the 2011 data set (8 ft) was similar continuing the trend of decreasing Secchi disk values. Since Secchi disk measurements are so closely linked with algal blooms, one hypothesis is that nutrient inputs to the lake or interactions with zebra mussels have resulted in reduced Secchi disk values. We are unaware of how abundant zebra mussels are in the lake, but typically when they enter an ecosystem, they increase water clarity, which results in more dense aquatic plant growth. Second, because they selectively remove edible algae from the water, blue-green algal blooms (*Microsystis*) (inedible by zooplankton) become prevalent. People should be aware of this and report any surface accumulations that look like green paint scum. In addition, we do not know if there has been an increase in boat traffic over the years, but boat traffic in general can destratify a lake, putting nutrients into the upper layers and since the lake is so shallow, sediments are constantly being disturbed and re-suspended into upper waters, also providing a source of nitrogen and phosphorus. This would foster algal blooms since the nutrient data show that both N and P are limiting at times in Sherwood Lake.

2009-2011: Devine dataset. These data (Table 2) taken in the south end of the lake, with appreciation to Dan Devine who collected them, show that the average value of the readings over the period 2 May-9 October have declined over the years from 10.9 ft in 2009, to 8.7 ft in 2010, to 8 ft in 2011. All these values would classify the lake as mesotrophic, since the cutoff value is >7.5 ft. Considering that zebra mussels are present and that there are ongoing efforts to reduce nutrient input to the lake, this trend is disappointing. Examination of the general seasonal trends over years shows that water clarity was high in spring, declines during summer algal blooms, then increases again in the fall. During 2009, as noted above, water clarity was moderately high compared with 2010-2011, and values varied from 10 to13 ft from 17 April through 6 October, with exceptions on 14 June (9 ft) and 4 August, when values were lowest of the year at 7 ft (Table 2). We would expect algal blooms may have been responsible for the loss of water clarity on these dates. During 2010, from 5 May through 23 July, Secchi disk values varied from 9 to 14 ft. The high value of 14 ft on 14 June 2010 was the highest recorded during the 3-year period. Thereafter, values declined to 6-9 ft during 4 August through 14 September and remained low for the rest of the period at 5-6 ft from 22 September to 6 October. This is contrary to the usual pattern we observed during other years, when Secchi disk values increased during late summer-fall; however, sampling further into October may have shown this trend. During 2011 from 4 May through 2 June Secchi disk values varied from 9 to 12 ft, declined to 7-8 ft during 27 June through 26 August, then decreased to 5-6 ft from 10 September through 2 October. From 9 September through 26 October, Secchi disk values increased from 7 to 11 ft.

Table 2. Secchi disk values (ft) for Lake Sherwood during 2009, 2010, and 2011. Data provided by Dan Devine.

2009		2010		2011	
18-Mar	Ice Out	19-Mar	Ice Out	2-Apr	Ice Out
17-Apr	11	5-May	11	4-May	9
2-May	10	22-May	10	12-May	10
7-May	12	1-Jun	12	17-May	10
16-May	13	14-Jun	14	21-May	11
25-May	12	21-Jun	12	25-May	12
5-Jun	11	1-Jul	11	30-May	11
14-Jun	9	5-Jul	9	2-Jun	9
26-Jun	10	13-Jul	10	27-Jun	8
9-Jul	12	15-Jul	10	20-Jul	7
13-Jul	11	23-Jul	11	23-Jul	8
22-Jul	10	4-Aug	9	4-Aug	8
31-Jul	10	16-Aug	8	16-Aug	8
4-Aug	7	21-Aug	9	26-Aug	7
25-Aug	12	9-Sep	6	10-Sep	6
5-Sep	10	14-Sep	8	17-Sep	6
25-Sep	11	22-Sep	6	22-Sep	6
26-Sep	12	25-Sep	6	25-Sep	6
6-Oct	13	28-Sep	5	28-Sep	5
		2-Oct	5	2-Oct	6
		4-Oct	5	9-Oct	7
		6-Oct	6	13-Oct	9

21-Oct	11
26-Oct	10

2011: Freshwater Physicians (2012). Secchi disk measurements during 14 August 2011 varied from 3.3 to 5.6 ft among the seven stations we sampled (Freshwater Physicians 2012) causing the lake to be classified eutrophic. Lake Sherwood stations (1, 2, 3, 7) had Secchi disc readings that varied from 3.3 ft to 5.6 ft, with the highest values observed at main lake stations, while the station 7 reading near the inlet stream (Wildwood River) was the lowest at 3.3 ft, indicating some intense coloring due to algal blooms or turbidity. These values found in Lake Sherwood are low and indicate a lake undergoing an algal bloom at this time.

2020: Freshwater Physicians (2021). Water transparency at stations 1-7 during fall 2020 on 16 September was 1.8-1.9 m (5.9-6.2 ft) or an average of 6.1 ft. These values are moderate and an indication of moderate degradation of the lake with more algal blooms and makes the lake eutrophic, since Secchi disk measures are <7.5 ft. Lakes are mesotrophic if the Secchi disk reading is between 7.5 and 15 ft, which has happened during specific times during various years in the past.

1980-2021: See sources above. We combined the data from 1980 to 2021 described in detail above, to provide an overall view of the long-term changes that occurred in Sherwood Lake over this period. As we noted above, the cutoff value for a lake to be eutrophic is to have readings <7.5 ft. Examination of the data (Fig. 8) showed that most average values are greater than 7.5 ft and sometimes they were over 14 ft. The overall conclusion is that the lake has mostly mesotrophic readings, which is very good. However, the overall trend starting from 1980 was for a decline from values of 10-14 ft down to around 5 ft during 2000; the readings then increased up to a maximum of around 15 ft on 2005 but began to decline again. Our 6.1 ft reading on 6 September 2020 and a similar reading during 2021 of 6.2 ft is close to the lowest Secchi disk reading for the whole period and shows that water transparency at least during summer is declining. A probable cause was the blue-green algae blooms we experienced and appeared to be more common place in recent years.

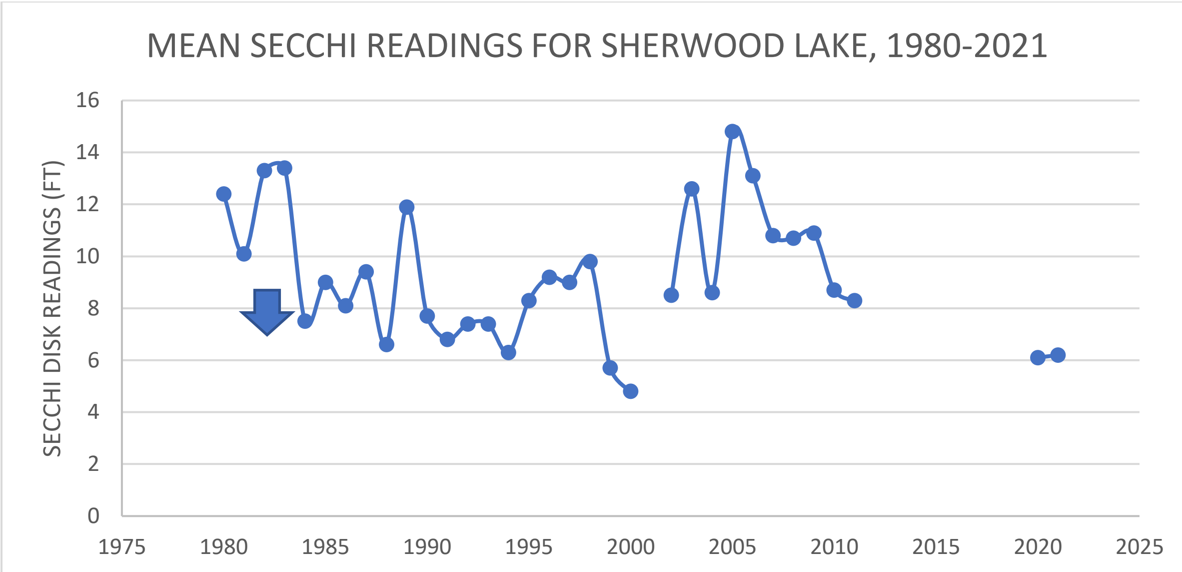

Figure 8. Water transparency data for Sherwood Lake, 1980-2020. Data from 1980-2010 (Fusilier 2010), 2009-2010 (D. Devine), 2020 (Freshwater Physicians 2020) and (this study). Blue arrow shows the point (<7.5 ft) that designates a lake eutrophic; above the line the lake is mesotrophic.

Temperature/Dissolved Oxygen

Water temperature is intimately associated with the dissolved oxygen profiles in a lake. The summer profile is the one that most characterizes a lake and the stratification impacts are very important. A lake goes through a series of changes (see introductory material- Temperature) in water temperature, from spring overturn, to summer stratification, to fall over turn, to winter conditions. During both summer and winter, rapid decomposition of sediments and detritus occurs when bottom waters are anoxic and can cause degraded chemical conditions on the bottom (internal loading: to be discussed). Because the lake is essentially sealed off from the surface when it is stratified during summer, no dissolved oxygen can penetrate to the bottom and anoxia (no dissolved oxygen conditions- a dead zone) can result. This has implications for the aquatic organisms (fish cannot go there) and chemical parameters (phosphorus and ammonia) are released from the sediments under anoxic conditions; these nutrients are then mixed into the lake during the fall and spring overturn fueling plant growth. The situation in Sherwood Lake is somewhat different. In some lakes, because they are shallow, boat activity and wind fetch can disrupt stratification patterns and re mix the accumulated nutrients into the water column during summer, a time when nutrients are mostly limiting in the lake. This can lead to more macrophyte and algae blooms, similar to what we observed in Sherwood Lake.

There were ten dissolved oxygen-temperature profiles performed from 1994 to 2008 (Fusilier 2010) during summer; six of them showed no stratification and no dissolved oxygen anoxia on the bottom. The four times when anoxia was found the lake was stratified and dissolved oxygen was zero at 17-19 ft. One can conclude from these data that Sherwood Lake is a shallow lake and that wind or motorized watercraft activity can disrupt stratification in the main body at the deep basin and re-oxygenate bottom waters. This seldom happens in deeper eutrophic lakes;

however, we have seen it happen in a deeper lake because of boat activity disrupting stratification, which probably happens on Sherwood Lake. The upshot of this is that occasionally Sherwood Lake is going to generate phosphorus and ammonia from decomposition of bottom waters during those times when the lake stratifies during summer (internal loading). Obviously, instead of the distribution of nutrients from this source which normally occurs during fall over turn, these nutrients generated will be distributed into the lake and provide nutrients during times when the supply of N and P may be low and limit plant growth. It of course could be worse and happen more often but needs to be taken in consideration when looking at nutrient sources and how to control them in Sherwood Lake.

The lake was not stratified during summer 2011 (Freshwater Physicians 2012), but dissolved oxygen was severely depleted to 0.5 mg/L on the bottom at station 1. During 16 September 2020 (Freshwater Physicians 2020) there was adequate dissolved oxygen from surface to bottom. During our fish sampling for this survey, dissolved oxygen was adequate in the bottom at one of the stations (G1- at the south end of the lake by the dam), but was low (almost zero) at station G2 in the eastern canal area (Fig. 6). Dissolved oxygen at this station would prevent fish from accessing the bottom where the coolest temperatures were available. This will stress fish such as northern pike and walleyes and cause little growth during this warm water period of the summer. Fortunately, at station G1 at the dam, there is some dissolved oxygen on the bottom, but it is below the required amount for warm water fish (3 mg/L) and cool water fish (5 mg/L). In addition, water temperatures (18-23.9 C) in the hypolimnion (bottom waters) was high, which will also tend to repel cool water fishes. One conclusion is that walleyes and northern pike will probably not do well in this eutrophic environment during summer.

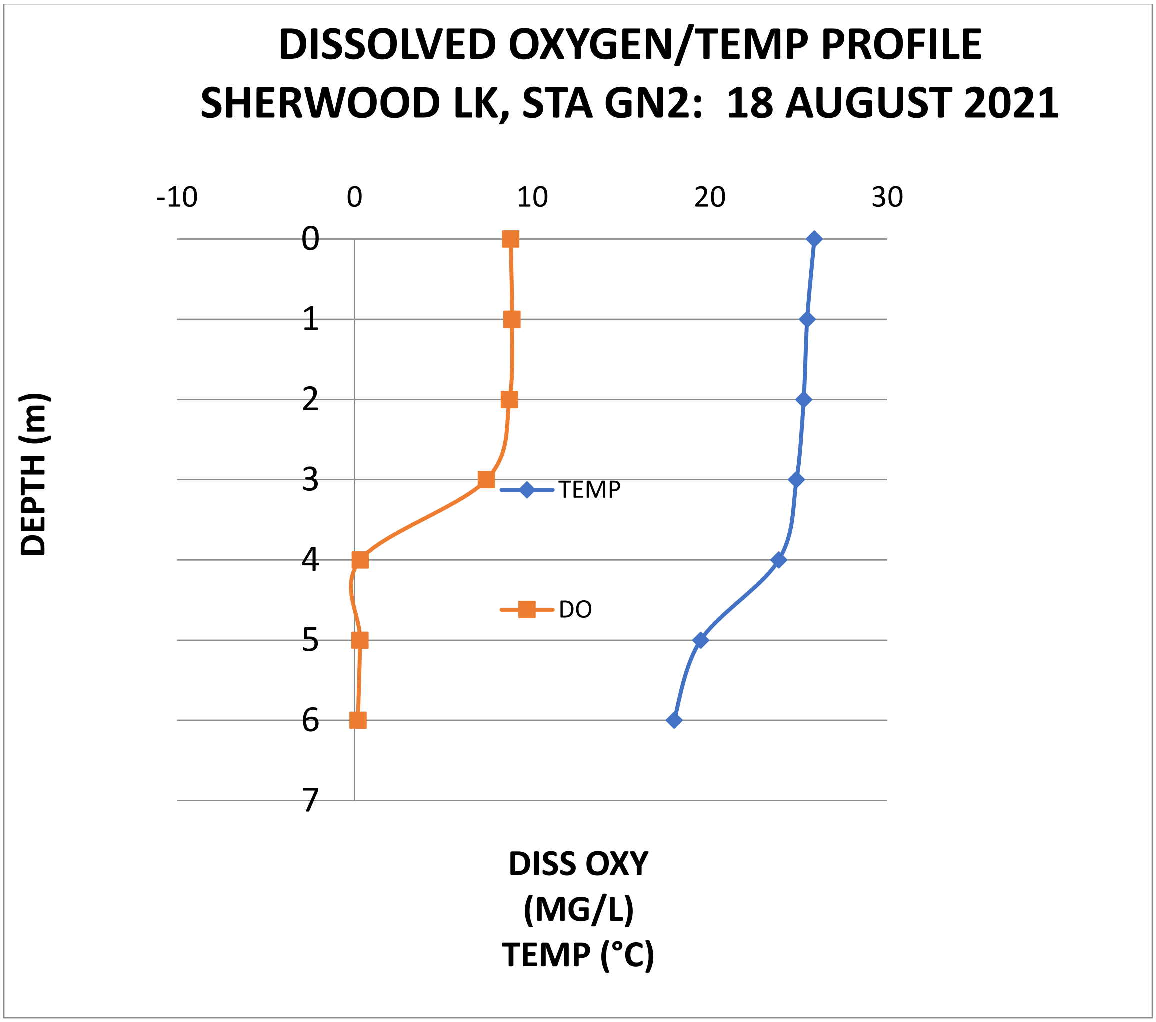

Figure 9. Dissolved oxygen-temperature relationships at station G2, Sherwood Lake, 18 August 2021. See map (Fig. 6) for station location.

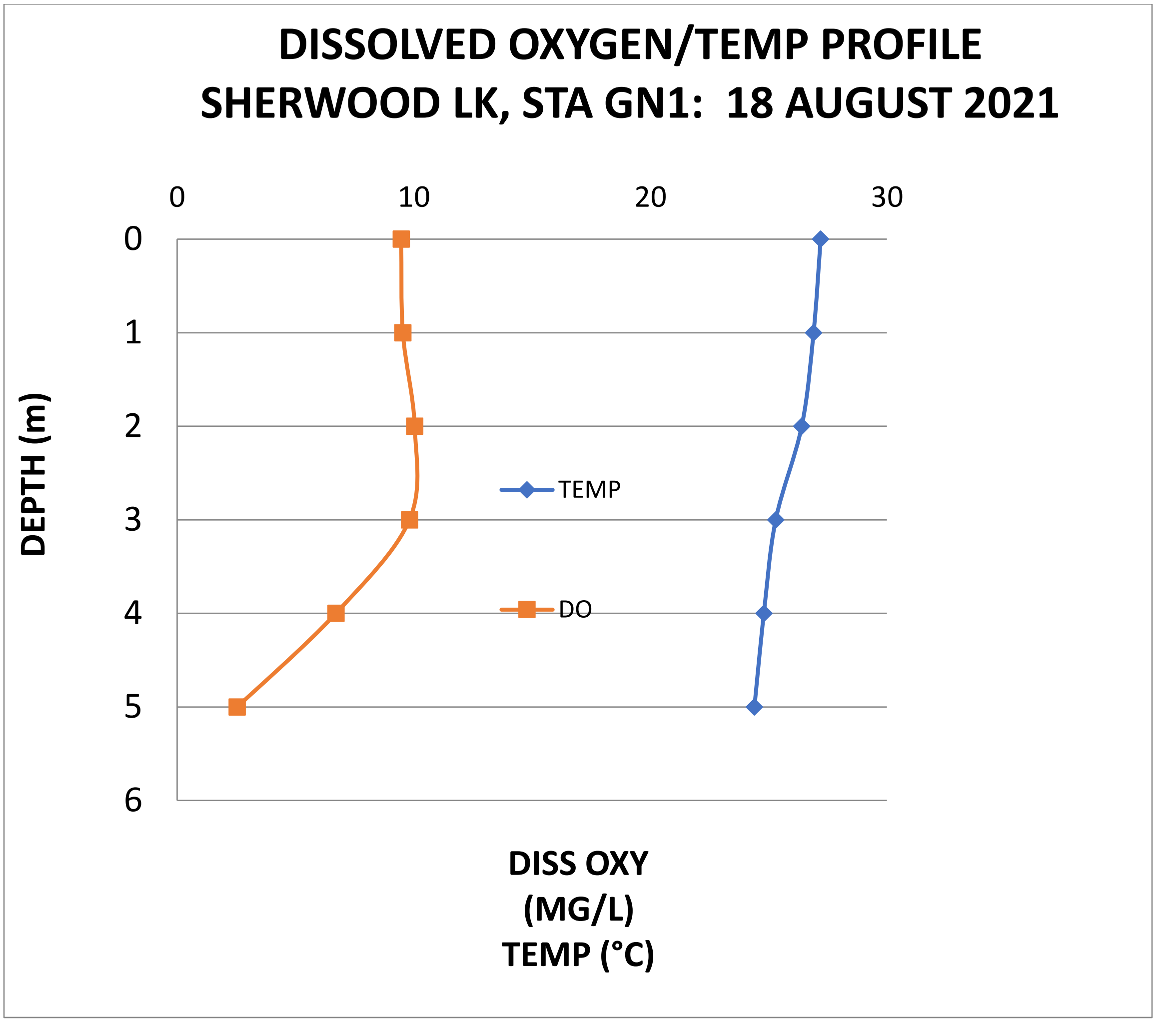

Figure 10. Dissolved oxygen-temperature relationships at station G1, Sherwood Lake, 18 August 2021. See map (Fig. 5) for station location.

BIOLOGICAL PARAMETERS

Zooplankton

We included the results of our sampling of zooplankton during our previous study (see Freshwater Physicians 2020) because we are interested in the linkages between zooplankton and fish predation in Sherwood Lake. During that study we sampled zooplankton at station 1 the master station and found no *Daphnia*, but other closely related groups (*Bosmina*, *Eubosmina*: crustaceans) made up 36% of the zooplankton community; the rest of the community was composed of copepods (see Picture 2 and 3) (Table 2). The absence of *Daphnia* is usually an indication of severe fish predation (large numbers of stunted bluegills, YOY yellow perch, or other planktivores). The answer to that will be discussed in the Fish section (below). The only other reason for no *Daphnia* is usually because of inedible blue-green algae in the lake. This could certainly be true, because of the blue-green algae bloom we observed first-hand during the fish study and the reports from EGLE of the occurrence of blue-green toxins in various places till way into fall. Some data on the composition of the algal blooms would shed light on this conundrum. Often we have also documented *Daphnia* doing vertical diel migrations under anoxic conditions remaining in the hypolimnion where fish cannot go and then rising to the surface at night to feed and avoid fish predation. That option is available to them in Sherwood Lake only around station G2.

Table 2. A listing of the abundance (% composition based on counting a random sample of at least 100 organisms) of zooplankton groups (see Picture 2-3) collected with a vertical tow from station 1 (G1) (master deep station) in Sherwood Lake, 16 September 2020 (see Fig. 6 for exact station location).

DATE: 10 SEPTEMBER 2020 LAKE: SHERWOOD STATION 1		
SPECIES	**COUNT**	**PERCENT**
Bosmina spp.	5	1.6
Cyclops ♀	5	1.6
Cyclops spp. ♂	2	0.6
Cyclops Imm.	14	4.5
Diaphanosoma spp.	91	29.5
Diaptomus Imm.	38	12.3
Diaptomus ♀	24	7.8
Diaptomus ♂	14	4.5
Eubosmina	106	34.4
Leptodora kindtii	9	2.9

Picture 2. A copepod (zooplankter).

Picture 3. *Daphnia*, a large zooplankter, adept at eating algae.

Fish

Fish Diversity

The fish diversity in Sherwood Lake was limited to 10 species, including 6 predators, 2 minnow species, and two centracharids- bluegills and black crappies (Table 3). The lake appears to be very productive, since we collected moderate quantities of bluegills, minnows – two minnow species-- bluntnose minnow and spotfin shiner; spotfin shiners are rare in most inland Michigan lakes. We also caught some large black crappies and bluegills. The presence of walleyes is also a positive sign that they can exist in this stressful environment, since the dissolved oxygen in one of the deep holes was almost zero and water temperatures were adverse for their growth and survival. Climate change will make this situation worse. The presence of rock bass adds another efficient predator to help control bluegill numbers.

Table 3. A list of the species, size ranges of saved fishes, and sample sizes used for this study. Fish were collected with seines (50 ft), trap nets, and gill nets, 18 August 2021. Catches were below expected, probably because of the high temperatures during this period.

Species	**Scientific name**	**Sample size**	**Size range (in)**
Black crappie	*Pomoxis nigromaculata*	7	4.5-12.1
Bluegill	*Lepomis macrochirus*	23	1.6-6.9
Bluntnose minnow	*Pimaphales notatus*	15	1.7-3.3
Largemouth bass	*Micropterus salmoides*	21	1.9-16
Pumpkinseed	*Lepomis gibbosus*	7	4-6.3
Rock bass	*Ambyloplitis rupestris*	1	9.6
Spotfin shiner	*Cyprinella spiloptera*	11	2.7-3.7
Walleye	*Sander vitreus*	1	18.6
Yellow bullhead	*Ameiurus natalis*	1	10.8
Yellow perch	*Perca flavescens*	16	2.9-10.8

Fish Diets

We examined seven black crappies that were 4.5 – 12.1 inches long (Table 4). The smallest one was eating zooplankton (to digested for species determination), while the rest were all piscivorous eating bluegills 39-55 mm and two unknown fish that were also probably bluegills. Obviously black crappies are a substantial predator on bluegills and will help to keep their numbers in balance in the lake. There are also large – sized individuals which will provide an excellent fishery for residents.

We sampled 23 bluegills 1.6-6.9 inches long. The smaller fish up to 4 in long were eating zooplankton (copepods and a bottom-dwelling species *Chydorus*), chironomids (insect larvae) which are abundant in the bottom muds, isopods, and amphipods *Hyalella*, sometimes called fairy shrimp. This is an excellent diet which is diverse and should provide food for good growth of this group. Fish 5 to 7 inches also ate a diverse diet composed of chironomids, mayflies (a great sign of good water quality), leeches, and ants. These larger fish also have a good diet that should lead to good growth.

We kept 15 bluntnose minnows that ranged from 1.7 to 3.3 inches. Bluntnose minnows are the most common minnow we see in lakes with minnows. They are adaptive and provide excellent forage for top predators. They appeared to be common and are a great addition to the fish fauna of Sherwood Lake.

The other minnow we caught was a spotfin shiner. We kept 11 of them that ranged from 2.-3.7 inches; they usually provide another prey fish for the predators, but none of those we sampled for diets had eaten any minnows. They are usually found on sandy beaches and stay nearshore so predators like largemouth bass have trouble catching them during summer. Later in the year when they move offshore they will be more susceptible to bass predation.

Largemouth bass is one of the most common and oft fished for species in Sherwood Lake. We kept 21 fish that ranged from 1.9 to 16 inches. From our observations, the small fish were young-of-the-year fish and appeared common enough to suggest good reproduction of this species. There certainly appeared to be adequate gravel and sand substrate for spawning. The small fish up to 3 in were eating zooplankton, specifically *Chydorus*, a species that is closely associated with the bottom. We did not catch this species in our zooplankton nets because of this reason. Fish from 3 in on were all piscivorous and one ate a crayfish. One had a fishing lure (large plastic worm) in its stomach. The fish eaten interestingly enough were all largemouth bass (47-65 mm) plus some unknown fish we could not identify. Apparently this group of bass was abundant and preferred over bluegills which were undoubtedly more common than largemouth bass. We would have liked to catch more larger fish, but they are not very susceptible to trap nets or gill nets.

Pumpkinseeds were less common than bluegills in Sherwood Lake; we caught seven (4-6.3 in). This species is known for eating snails and other mollusks, but only one fish had eaten snails. All the others were insectivorous eating: *Hyallella* an amphipod, mayflies (Baetidae), and chironomids. As noted before, the appearance of mayflies in the diet is a great sign that there still are places in Sherwood Lake where there is high water quality and adequate dissolved oxygen to support this fragile species. These fish are a great addition to the fish community especially since they usually occupy a different niche than other fishes by eating snails and mollusks.

We only got one rock bass (9.6 in) so they must be rare in the lake. They are usually more abundant. They feed on fishes and especially like crayfish and provide a good fish for sport fishing as well.

Yellow perch are great sports fish because of their unique flavor, but they are also sought after by northern pike and walleyes as prey. However, there are few of these species in the lake, not enough to make a difference. We have seen a truncated length distribution in lakes with many northern pike and walleyes. We saved 16 fish that were 2.9 in (YOY) to 6.2 in. We would have liked to see more larger fishes and there certainly seems to be adequate benthos and forage fish to grow bigger fishes. Apparently predation must be a large factor than expected, or we would have captured larger individuals. There did seem to be enough YOY in our catches to suggest that reproduction was adequate for this species.

One yellow bullhead was collected in the gill nets; it was 10.8 in and true to form these fish can be good predators reducing the bluegill population. This one ate one bluegill 55 mm and one yellow perch 75 mm (ca. 3 in). Again these fish are important members of the fish community and can help control bluegill populations.

Lastly, one large walleye (18.6 in) was collected that was released. They have been stocked in the past and some survive, despite the lack of dissolved oxygen in their preferred temperature zone (see Fig. 3 – fish squeeze). Sherwood Lake is not an appropriate lake for stocking this cool-water species because of the inadequate environmental conditions in the lake. People should go to Lake Erie or Saginaw Bay where conditions are much more favorable. They will not spawn in Sherwood Lake, conditions are terrible for them, and they are difficult to catch. Certainly no more stocking would be recommended unless all are aware of the cost, return to fishers, and impacts on the fish community. There have been lakes where too many were stocked and they lost lake herring in the lake.

Table 4. Listing of the species collected, length, weight, sex, and diet information for fishes from Sherwood Lake, Oakland County, MI 18 August 2021. LB=largemouth bass, BC = black crappie, YB = yellow bullhead, BG = bluegill, PS = pumpkinseed, YP = yellow perch, SF = spotfin shiner, WL = walleye, BM = bluntnose minnow, RB = rock bass. ZOOP = zooplankton, M = male, F= female, 1= poorly developed gonads, II = immature. XX = unknown, MT = empty stomach.

GEAR	SPECIES	LEN IN	WT (OZ)	SEX	DIET
		BLACK CRAPPIE			
S1	BC	10.8		F1	XX FISH
S1	BC	12.1		M1	BG 39, 42 MM
S1	BC	10.6		M1	BG 48, 55 MM
S1	BC	10.0		F2	XX FISH
S1	BC	9.0		M1	MT
G2-1	BC	9.4		F2	MT
G2-1	BC	4.5		II	ZOOPLANKTON
		BLUEGILL			
S1	BG	1.6	0.03	II	MT
S4	BG	2.4	0.10	II	ZOOPLANKTON COPEPODS AND OTHERS
S4	BG	2.5	0.13	II	ZOOPLANKTON
G2-1	BG	2.8	0.16	II	DETRITUS
G2-1	BG	2.8	0.18	II	DETRITUS
TN-1	BG	2.8		II	30 CHIRONOMIDS, 20 OSTRACODS
GN1-2	BG	2.8	0.19	II	ZOOPLANKTON CHYDORUS, ISOPODS
S4	BG	3.2	0.26	II	HYALELLA, CHIRONOMIDS, INSECT PARTS
S4	BG	3.4	0.30	F1	MT
G2-1	BG	3.7			ZOOPLANKTON
GN1-2	BG	3.9	0.49	II	15 CHIRONOMIDS, 10 HYALELLA (AMPHIPODS OR FAIRY SH
GN2-1	BG	5.2	1.37	II	MT
GN2-1	BG	5.4	1.53	F1	CHIIRONOMIDS, MAYFLIES, INSECT PARTS

GN2-1	BG		6.0	2.52	F2	80 CHIRONOMIDS, 5 MAYFLIES
GN2-1	BG		6.2	2.36	F1	INSECT PARTS, ANT
S2	BG		6.2	2.60	F1	MT
GN2-1	BG		6.3	2.28		CHIRONOMIDS, MAYFLIES
GN2-1	BG		6.4	2.65	F1	CHIRONOMIDS, INSECT PARTS
GN2-1	BG		6.6	3.15	M1	LEECH, MAYFLIES
S1	BG		6.7	2.85	M1	MANY SEEDS, CHIRONOMIDS
GN2-1	BG		6.8	2.94	M1	INSECT PARTS
GN2-1	BG		6.9	2.99	F1	
		BLUNTNOSE MINNOW				
S5	BM		1.7	0.02		
GN2-1	BM		1.7	1.50		
S5	BM		1.7	0.02		
S5	BM		1.7	0.02		
GN2-1	BM		1.8	1.61		
S5	BM		1.9	0.03		
S5	BM		2.0	0.03		
S2	BM		2.0	0.04		
S2	BM		2.2	0.05		
S2	BM		2.2	0.06		
S2	BM		2.5	0.06		
S2	BM		3.1	0.14		
S2	BM		3.2	0.15		
S2	BM		3.3	0.17		
S2	BM		3.3	0.20		
		LARGEMOUTH BASS				
S1	LB		1.9	0.04	II	MT
S1	LB		2.0	0.05	II	MT
S1	LB		2.1	0.04	II	MT
S1	LB		2.2	0.08	II	MT
S4	LB		2.8	0.14	II	ZOOPLANKTON *CHYDORUS*
S1	LB		2.8	0.12	II	MT
GN2-1	LB		3.5	0.27	II	XX FISH
S1	LB		5.0	0.87	II	MT
S2	LB		5.1	0.80	M1	MT
S4	LB		5.3	1.07	FI	LB 57 MM
S1	LB		5.7	1.26	F1	MT
S2	LB		5.8	0.00	II	LB 49 MM
S4	LB		5.8	1.55	F1	LB 58 MM
S5	LB		6.3	1.80	F1	XX FISH 35 MM
S2	LB		6.4	2.00	F2	LB 52 MM

S2	LB	6.4	1.94	M1	XX FISH (?LB 40 MM)
S1	LB	6.5		II	LB 66 MM
S2	LB	6.8		II	LB 62 MM
S4	LB	7.1		M1	LB 65 MM
S2	LB	15.5		F1	LB 47 MM,PLASTIC WORM
S2	LB	16.0		M1	CRAYFISH
		PUMPKINSEED			
S4	PS	4.0	0.65	F2	MT
S4	PS	4.3	0.83	F2	HYALELLA
S4	PS	4.5	0.93	F1	PLANTS, DETRITUS
GN2-1	PS	4.9	1.27	II	MAYFLIES, CHIRONOMIDS
S4	PS	5.6	1.76	F1	HYALELLA, MAYFLIES
GN2-1	PS	6.1	2.53	F1	100 CHIRONOMIDS, WORM
GN2-1	PS	6.3		F2	SNAIL, MAYFLIES (BAETIDAE), CHIRONOMIDS
		ROCK BASS			
G2-1	RB	9.6		F1	MT
		SPOTFIN SHINER			
S5	SF	2.7	0.10		
S5	SF	2.8	0.10		
S5	SF	2.9	0.10		
S5	SF	2.9	0.13		
S5	SF	3.0	0.12		
S5	SF	3.0	0.12		
S5	SF	3.1	0.14		
S5	SF	3.1	0.12		
S5	SF	3.1	0.14		
S5	SF	3.1	0.12		
S5	SF	3.7	0.20		
		YELLOW PERCH			
S2	YP	2.9	0.14	II	ZOOPLANKTON
S2	YP	3.0	0.14	II	CHIRONOMIDS, MAYFLIES
S1	YP	3.0	0.16	II	MAYFLIES, HYALELLA, CHIRONOMIDS, CADDISFLIES
S1	YP	3.2	0.16	II	MAYFLIES, ZOOPLANKTON, CHIRONOMIDS
S4	YP	4.3	0.42	F1	SNAILS, MAYFLY, ZOOPLANKTON CHYDORUS
S4	YP	4.4	0.47	F1	MAYFLIES, INSECT PARTS
S4	YP	4.5	0.48	F1	MT
S4	YP	4.5	0.51	F1	MAYFLIES, CHIRONOMIDS
GN1-2	YP	4.7	0.52	M1	MT
S4	YP	4.7	0.54	F1	ZOOPLANKTON CHYDORUS, CHIRONOMIDS
S4	YP	4.7	0.55	M1	MAYFLIES, INSECT PARTS
S4	YP	4.8	0.59	F1	CRAYFISH
S4	YP	5.0	0.67	F1	MT
S4	YP	5.4	0.86	F1	MT

S1	YP		6.2	1.43	F1	MT
G2-1	YB		10.8		M1	YP 75 MM, BG 55 MM
		WALLEYE				
T2	WL		18.6			

Fish Age and Growth

Part of managing a fish population is to determine if there are fish that are not growing well or growing too fast can be a detriment as well. Growth can identify species that are not adapting or fitting well into a well-balanced fish community or those that may be stunted suggesting more predators may be needed to reduce numbers. For example, bluegills can be so numerous that they can harass and eat the eggs of largemouth bass on their nests, reducing their survival in a lake. Overall, we saw no problems with the growth of the fishes we examined in Sherwood Lake. There were some ups and downs, but these were all minor. During our sampling we also kept a mental note of the abundance of the various species we collected to determine if they were scarce, dominated by one group, too abundant, or for many species, whether YOY were common or rare, which can indicate if successful reproduction is ongoing. One finding which we noted already was in some cases, a lack of catching more fish than we assumed would be vulnerable, especially in the gill nets. We observed this phenomenon in other lakes we sampled during 2021 and attributed it to the hot summer we recorded during 2021, either congregating fish in places we did not sample or slowed down their movements. Never-the-less, we did get enough fish from seining and contributions from Dan Devine to fill in some of the gaps in sizes we needed for good growth estimates. Species accounts follow below.

We collected and aged 20 bluegills from various places on Sherwood Lake during summer 2021. The largest fish we caught was around 7 in, which is a nice fish, but we expected them to be somewhat larger to provide a good fishery. Certainly, we could have missed sampling them if they were sequestered in some special places in the lake we failed to sample. Generally, growth was good and was comparable to MDNR averages for Michigan lakes (Fig. 11, Table 5). There did not seem to be an over abundance of YOY, so we did not expect to see any stunting and our seine catches were as expected.

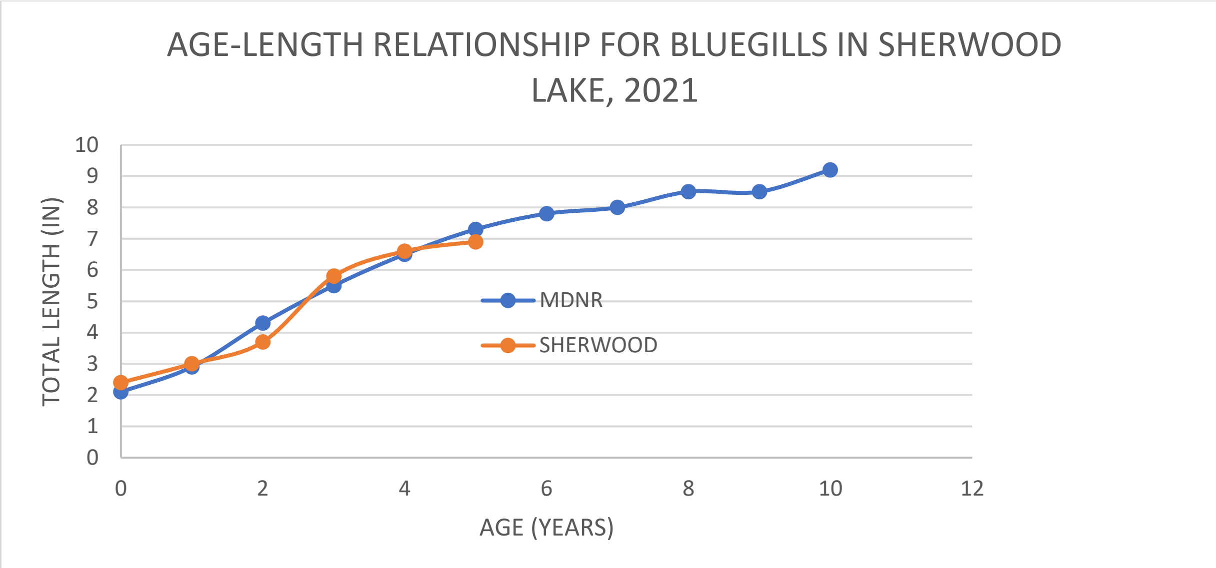

Figure 11. Age- length relationship for bluegills sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=21.

Table 5. Age and growth data for several fish species collected in Sherwood Lake, summer 2021 compared with MDNR average lengths for each age group. Length in inches; sample size in parentheses.

MDNR AGE(YR)	MNDR LEN (IN)	SHERWOOD LEN (IN)
BLUEGILL		**N=20**
AGE	**MDNR**	**SHERWOOD**
0	2.1	2.4(5)
1	2.9	3(2)
2	4.3	3.7(3)
3	5.5	5.8(4)
4	6.5	6.6(5)
5	7.3	6.9(1)
6	7.8	
7	8	
8	8.5	
9	8.5	
10	9.2	
LARGEMOUTH BASS		**N=19**
AGE	**MDNR**	**SHERWOOD**

0	3.3	2.5(7)
1	6.1	5.1(3)
2	8.7	6(5)
3	10	6.4(1)
4	12.1	
5	13.7	
6	15.1	
7	16.1	16(3)
8	17.7	
9	18.8	
10	19.8	
11	20.8	

YELLOW PERCH **N=15**

AGE	MDNR	SHERWOOD
0	3.3	3(3)
1	4	4.5(9)
2	5.7	5.2(2)
3	6.8	5(1)
4	7.8	
5	8.7	
6	9.7	
7	10.5	
8	11.3	
9	11.7	

BLACK CRAPPIE **N=7**

AGE	MDNR	SHERWOOD
0	3.6	
1	5.1	4.5(1)
2	5.9	
3	8	
4	9	9(1)
5	9.9	9.7(2)
6	10.7	10.7(2)
7	11.3	
8	11.6	
9		12.1(1)

PUMPKINSEED **N=7**

AGE	MDNR	SHERWOOD
0	2	
1	2.9	
2	4.1	4.2(2)
3	4.9	4.7(2)
4	5.7	5.6(1)

5	6.2	6.2(2)
6	6.8	
7	7.3	
8	7.8	
WALLEYE		**N=3**
AGE	**MDNR**	**SHERWOOD**
0	6.6	
1	9.1	
2	12	
3	15.9	
4	17.8	
5	18.9	
6	18.8	
7	18.8	18.6(2)
8	21.4	20.8(1)
9	19.7	
10	22.6	
ROCK BASS		**N=1**
AGE	**MDNR**	**SHERWOOD**
0	1.5	
1	3.2	
2	4.3	
3	5.2	
4	6.2	
5	7.3	
6	7.9	
7	8.8	
8	9	
9	9.9	9.6(1)
10	10.5	
NORTHERN PIKE		**N=1**
AGE	**MDNR**	**SHERWOOD**
0	7.9	
1	15.5	
2	19.4	
3	22.2	20(1)
4	23.9	
5	25.4	
6	27.7	
7	32.5	
8	37.1	
9	34.8	
10	44.4	

We examined 19 largemouth bass for ages and found they too were growing at expected lengths for given ages, suggesting adequate forage for them to grow at average rates (Fig. 12, Table 5). It appeared that there was an adequate abundance of YOY largemouth bass from our seine hauls, suggesting good reproduction by this species. There certainly appeared to be adequate spawning substrate (gravel and sand) for them to make nests.

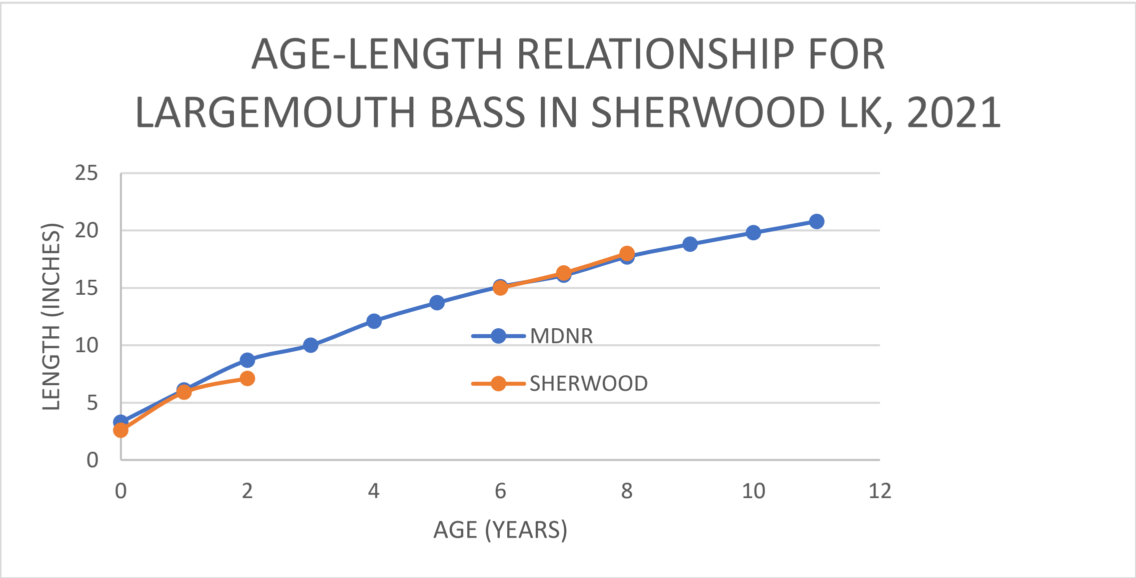

Figure 12. Age- length relationship for largemouth bass sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=19.

We examined 15 yellow perch from Sherwood Lake. Our gill nets are very effective at catching fish with such opercles that readily get caught in the mesh. The fact that the largest fish we got was 5.2 inches, indicates that there are not many larger than 5 inches in the lake. In addition, we only caught three YOY and did not see any more in the nets, suggesting poor reproduction or heavy predation. Consultation of the diet information (Table 4) shows that the black crappies were eating bluegills, the largemouth bass were eating other largemouth bass, and the yellow bullhead we caught had eaten one of each: bluegill and yellow perch. Northern pike and walleyes are notorious for eating yellow perch, but they are uncommon in the lake and probably do not exert a lot of pressure on this species. It seems like they are reproducing enough to sustain the population, but are undergoing predation pressure keeping their numbers low. Stocking more will not help this situation.

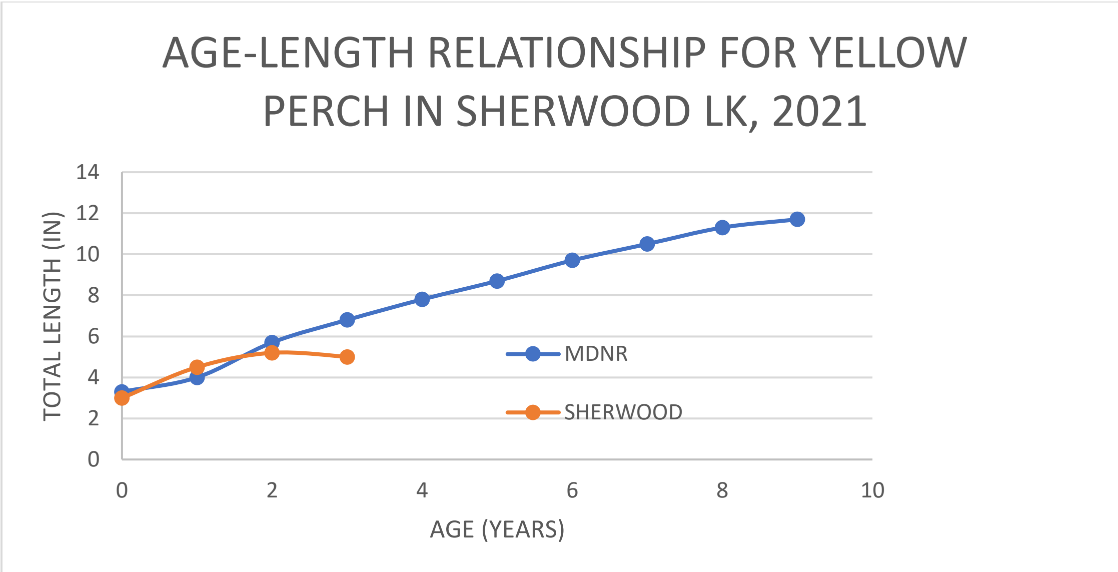

Figure 13. Age- length relationship for yellow perch sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=15.

We managed to find a spot to seine where there were a large accumulation of large black crappies, which helped to fill out our need for larger black crappies and show that they are present in some numbers in the lake and providing an important function in eating a lot of YOY bluegills (Table 4). The seven fish we aged had one fish that was old (9 years old, 12 inches long) and all were growing at expected rates (Fig. 14, Table 5). There was a lack of YOY however, which is unfortunate. Usually with a large number of large adults, they successfully spawn, and we should have seen at least some YOY fish in our extensive seine hauls.

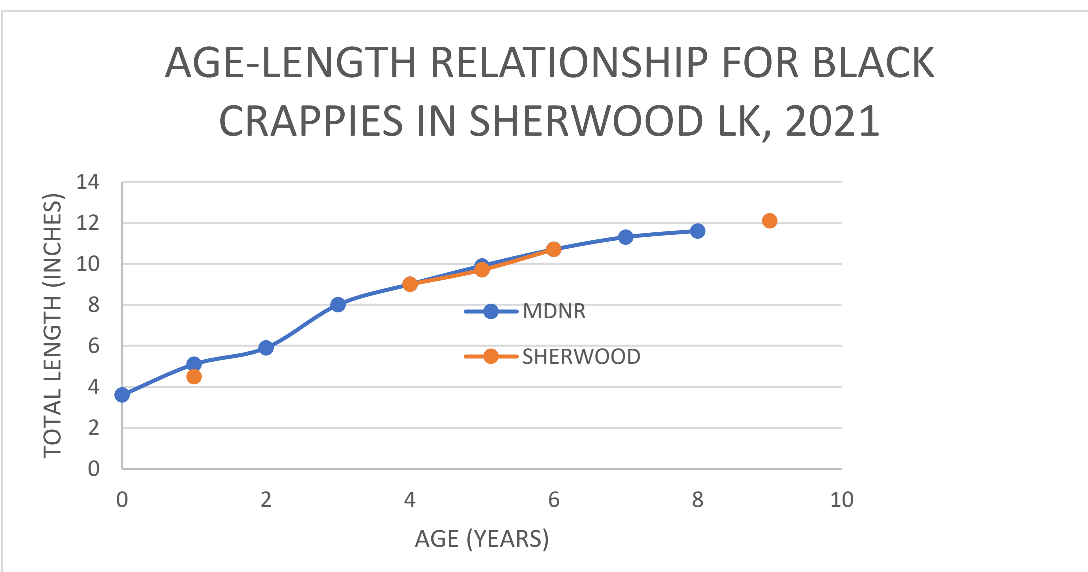

Figure 14. Age- length relationship for black crappies sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=7.

Pumpkinseeds were uncommon in Sherwood Lake; we only caught seven. It was especially noteworthy that we did not catch any YOY or yearlings, an indication of poor reproduction. Again, there seems to be adequate substrate for these fish to spawn. Growth however, for the 2 to 5 year olds, was at Michigan averages (Fig. 15, Table 5). Pumpkinseeds are unique among other centrachids (sunfish) in that they prefer to eat snails and mollusks. The fact that the lake association treats the lake with copper sulfate to control algae probably depresses pumpkinseed growth, since copper kills snails and mollusks. Another far-ranging effect of treatment of macrophytes and algae, we seldom think about.

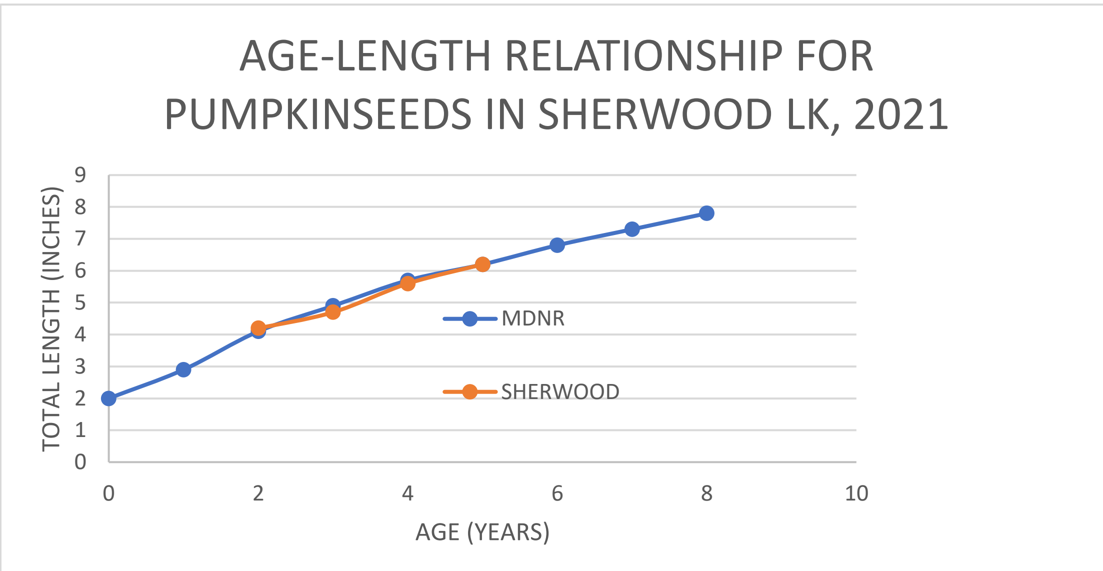

Figure 15. Age- length relationship for pumpkinseeds sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=7.

Walleyes have been stocked into Sherwood Lake in the past and a few have survived for long periods of time (8 years); we collected one (released) and Dan Devine provided scales from two others. These fish were growing at Michigan state averages, so obviously found enough forage to grow well in the lake, despite unfavorable water quality during summer (see Fig. 3 – fish squeeze). Water temperatures are too warm for them during summer and the coolest temperatures in the deep holes have low dissolved oxygen during some periods. We suspect that growth is low or zero during summer but accelerates during the cool periods of the year. They are known to prefer yellow perch and lakes with them present usually have a reduced yellow perch population. This same scenario exists for northern pike. We generally do not support stocking walleyes into a lake where they are not native and cannot spawn, where the water quality suggests it is optimal for a warm water fishery (bluegills, largemouth bass), not a cool water fish, where the newly introduced walleyes can detrimentally affect forage or a sports fish (yellow perch, lake herring), where they are difficult to catch, and where the cost benefit to fishers is low.

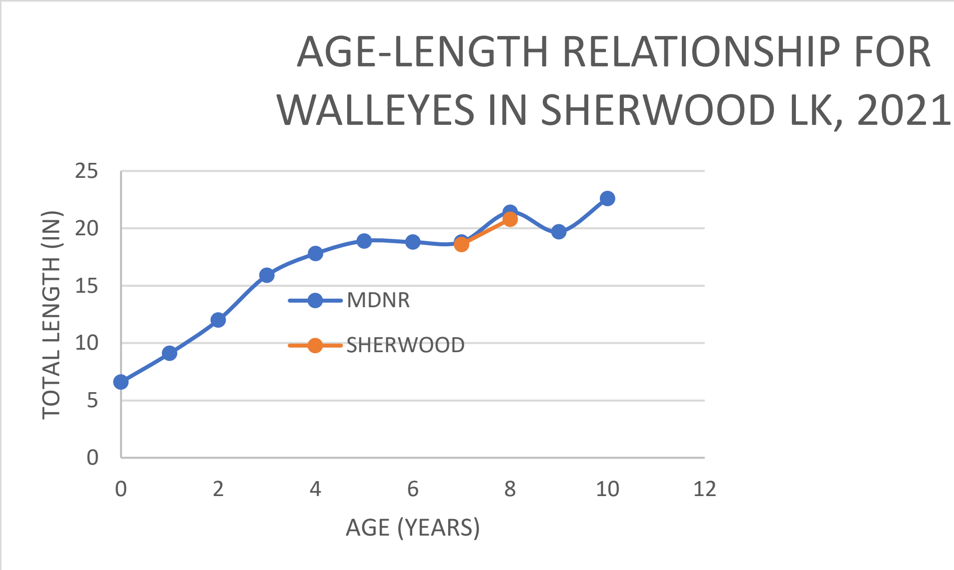

Figure 16. Age- length relationship for walleyes sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=3.

We only caught one large rock bass (9.6 in) that was 9 years old (Fig. 17, Table 5). No YOY were observed or caught, which suggest this fish is rare in the lake. That is unfortunate, since this species adds biodiversity, consumes bluegills, and is a good sports fish to catch.

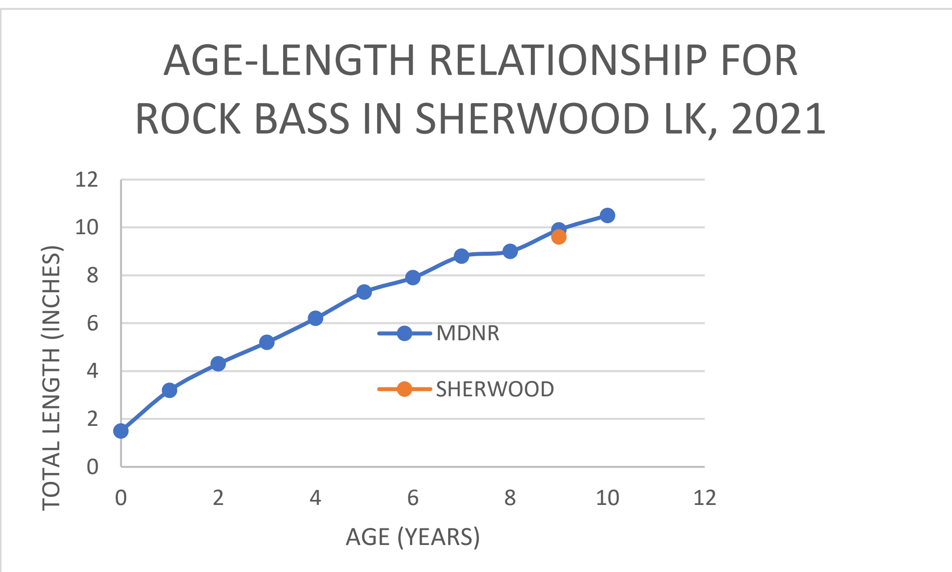

Figure 17. Age- length relationship for rock bass sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=1.

Apparently northern pike are rare in Sherwood Lake; we caught none in the gill nets and one was submitted by Dan Devine. That fish was 18 inches and 3 years old. So, some reproduction occurs in the lake. The lake appears to have several places (tributaries, canals, inlets, aquatic plants nearshore) where they could spawn. They are important top predators and since they apparently have low survival, they might be a candidate for stocking if there was an interest in increasing the supply of this predator. As noted for walleyes, this fish is often native to inland lakes but is subject to the same problems as walleyes are noted above. They are cool water fish and would be stressed during summer with warm temperatures and low dissolved oxygen concentrations in the coolest water available during some periods.

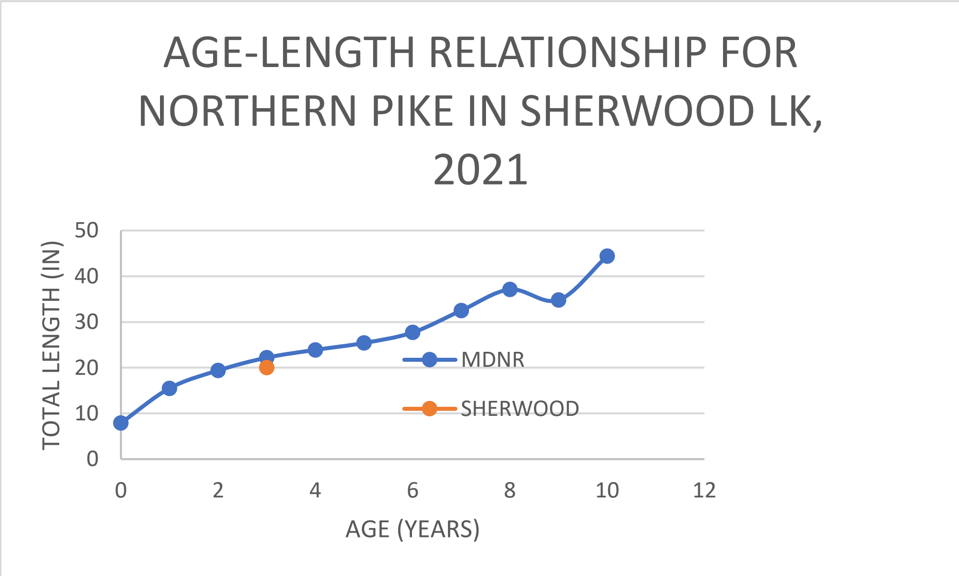

Figure 18. Age- length relationship for northern pike sampled from Sherwood Lake during summer 2021 (red line) compared with MDNR averages (blue line). N=1.

DISCUSSION

Sherwood Lake water quality and zooplankton data were gathered in a previous study (Freshwater Physicians 2020) so for a good discussion of detriments to lake ecosystem integrity and recommended solutions and management efforts, consult this report. In this discussion we will focus on zooplankton and fishes.

Sherwood Lake is a shallow, 256-acre, dammed, eutrophic lake surrounded by extensive development and houses (320 riparians). There are two major inlets, one outlet, many smaller storm drains, and the lake has an extremely high shoreline development index, meaning it has many bays, channels, and bayous where additional housing has been built, which results in additional impact on the lake's ecological integrity. Unlike most eutrophic lakes, Sherwood Lake is somewhat different since its deepest basin is around 20 ft; it does not always stratify in summer but does when conditions (calm weather and low boating activity) allow. This has implications: some good and some bad. When anoxia forms during stratification, fish are prevented from that area on the bottom that is devoid of dissolved oxygen. The positive aspect of this situation is that there is generally dissolved oxygen from the surface to the bottom from wind fetch and boat activity that mixes the lake, puts oxygen on the bottom, thereby allowing fish access to food items and it prevents nutrient regeneration from bottom sediments. The exotic Eurasian milfoil and starry stonewort are present in the lake and need to be controlled while not harming native species, which are critical habitat for insects, fishes, and they thwart wave action, which destratifies the lake and stirs up sediments that release nutrients. There has been a macrophyte and algae control program ongoing in Sherwood Lake to address excess growth in specific areas of the lake. Algae and macrophytes need to be observed closely as manifestations of some of the elevated nutrient concentrations we found. We discourage treatment of algae and prefer manual methods (raking) to make suitable clearing of beaches for recreational use. In addition, copper accumulates in the sediments killing snails and other benthic organisms and once algae is killed it decomposes and recycles N and P which can then result in another algal bloom. The blue-green algae blooms we observed and apparently were common through fall, is a symptom of over enrichment. Runoff from fertilized lawns which are prevalent in the riparian zone is a likely culprit. There were no *Daphnia* in our summer 2020 zooplankton sample, but there were some closely related groups that composed 36% of the community. The remining community was composed of copepods, which are not as efficient at removing algae and more difficult for fishes to catch. We believe fish predation may be one of the reasons for lack of *Daphnia*, but no fish we examined were eating *Daphnia*. A more likely explanation is the proliferation of blue-green algae, which are inedible for zooplankton.

There were 10 species of fishes caught during our survey. We did not catch as many as we thought, which was the case in a couple other lakes we surveyed that summer. We attributed the lower catches to the hot temperatures, which may have slowed down fish activity. Of particular concern was the few large largemouth bass we caught; however, they are problematic and not very susceptible to our gill nets and trap nets. Still that is a low number of species for a Michigan inland lake, which has an abundance of different habitats and water niches.

MANAGEMENT RECOMMENDATIONS

Sherwood Lake is a eutrophic lake, which "occasionally" develops anoxia (no dissolved oxygen) on the bottom during summer stratification, which leads to a potential fish problem: It stresses cool-water fish like northern pike and walleyes, which are forced to survive in a thin layer of optimal water or no optimal water at all. There has been a long-term decline in water transparency, with recent Secchi disk readings at only 6 ft, which is probably related to the proliferation of blue-green algae blooms, also detrimental to zooplankton, mandatory food for young and some old fishes. There has been extensive efforts to control macrophytes and algae, which can reduce fish habitat and pollute sediments with copper, killing mollusks, food for pumpkinseeds, which were scarce in our survey. Overall, we have only a few fish management recommendations. Catch and release of the large largemouth bass and northern pike to allow for spawning. The larger fish are probably contaminated with mercury from air borne sources anyway, so consult the MDNR fishing guide for suggested consumption recommendations and advisories. We know that most fishers practice this anyway and strongly support the effort. There should be no stocking of walleyes, since they are severely stressed, not native to the lake, can disrupt the ecological balance of the fish community, consume prey that other natives could eat, are difficult to catch, and will not successfully spawn in Sherwood Lake. This relates to other species as well. You have two species of minnows which should be adequate to provide prey for predators; sunfish, largemouth bass, and crappies are prolific spawners, and appear to have unlimited areas (gravel and sand) for spawning, and yellow perch are not limited by spawning but probably by predation, so stocking them would be a waste. Northern pike are a cool water species and are probably limited in their spawning and would be the only fish justified in stocking. However, as noted they appear to be scarce in the lake and will, like walleyes, be severely stressed during summer, so stocking them would probably be a waste as well.

Merna (1981) found 15 species of fishes, 5 more than we did. Those included smallmouth bass, longear sunfish, bowfin, green sunfish, and white sucker. Yellow perch reached 11 inches, much larger than ours, and bluegills reached 7.6 in, also a bit longer than ours, indicating that the fishery was much better than it is now. Northern pike were rare as now and largemouth bass were the dominant predator. Schneider (2003) found the lake fishery in good shape as well, and had no major recommendations except one: stocking golden shiners, which we heartily support. He found 13 species, 3 more than during our study. They were common carp, green sunfish, and smallmouth bass. It should also be noted that stocked walleyes were growing well, but that there was a lot more macrophytes present during his study.

SUMMARY OF RECOMMENDATIONS

1. Be careful in treating algae and macrophytes; plants are critical habitat for fishes and fish food, retard wave action, and help to keep algae from dominating a lake ecosystem.
2. Catch and release of large predators is recommended to promote spawning and allow more than one person to catch each of these valuable fish which take many years to grow to catchable sizes.
3. We recommend against stocking any more walleyes, unless all are aware of the pros and cons of doing it, especially low returns and impacts on prey species.
4. Schneider recommended stocking golden shiners as an additional forage fish for predators. We support this recommendation.
5. The lake is not optimal fish habitat because of the blue-green algae blooms we observed and were alerted to during late summer and fall. Residents need to practice some of the measures we noted in our former report and in the appendix here to reduce nutrient input to the lake. The blue-green algae can be dangerous to swimmers and pets, are not able to be eaten by zooplankton, depress water clarity, and can lead to a shift from a macrophyte dominated lake to a algae-dominated one. Climate change is only going to exacerbate these detrimental changes; act now.

ACKNOWLEDGEMENTS

I want to thank Dan Devine for his help in coordinating the study, for providing a vessel and guidance on the lake. Royce assisted us in sampling as recorder, net hauler, and fish handler. Jason Jude provided help with some of the figures. Sherwood Lake residents should be appreciative of the efforts of some of its residents who care about the ecological integrity of the lake. We ask that they share in the care of the lake by taking heed of the measures we suggest that will help maintain or reverse some of the degrading influences on the water quality of the lake.

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Merna, J. 1981. Sherwood Lake fish survey. Merna report 15 pp.
Schneider, J. 2003. The 2003 fish survey of Sherwood Lake. Lake and Stream Consultants, 805 N. Wagner Rd., Ann Arbor, MI. Fish Report 17, 23 pp.

APPENDIX 1

Appendix 1. Guidelines for Lake Dwellers; some may not apply.

1. DROP THE USE OF "HIGH PHOSPHATE' DETERGENTS. Use low or no phosphate detergents or switch back to soft water & soap. Nutrients, including phosphates, are the chief cause of accelerated aging of lakes and result in algae and aquatic plant growth.

2. USE LESS DISWASHER DETERGENT THAN RECOMMENDED (TRY HALF). Experiment with using less laundry detergent.

3. STOP FERTILIZING, especially near the lake. Do not use fertilizers with any phosphate in them; use only a nitrogen-based fertilizer if you must. In other areas use as little liquid fertilizer as possible; instead use the granular or pellet inorganic type. Do not burn leaves near the lake. Dispose of leaves outside the watershed.

4. STOP USING PERSISTENT PESTICIDES, ESPECIALLY DDT, CHLORDANE, AND LINDANE. Some of these are now banned because of their detrimental effects on wildlife. Insect spraying near lakes should not be done, or at best with great caution, giving wind direction and approved pesticides first consideration. We are experiencing silent spring all over again in recent losses of frogs, birds, and insects, critical components of our ecosystem. Don’t contribute to this continuing loss.

5. PUT IN SEWERS IF POSSIBLE. During heavy rainfall with ground saturated with water, sewage will overflow the surface of the soil and into the lake or into the ground water and then into the lake.

6. MONITOR EXISTING SEPTIC SYSTEMS. Service tanks every other year to collect and remove scum and sludge to prevent clogging of the drain field soil and to allow less fertilizers to enter the groundwater and then into the lake.

7. LEAVE THE SHORELINE AND YOUR LAWN IN ITS NATURAL STATE; PLANT GREEN BELTS. Do not fertilize lawns down to the water's edge – it is now the law. The natural vegetation will help to prevent erosion, remove some nutrients from runoff, and be less expensive to maintain. Greenbelts and water gardens should be put in to retard runoff directly to the lake. Consult the Michigan Shoreline Partnership for guidance and examples of native plants for green belts.

8. CONTROL EROSION. Plant vegetation immediately after construction and guard against any debris from the construction reaching the lake.

9. DO NOT IRRIGATE WITH LAKE WATER WHEN THE WATER LEVEL IS LOW OR IN THE DAYTIME WHEN EVAPORATION IS HIGHEST.

10. STOP LITTER. Litter on ice in winter will end up in the water or on the beach in the spring. Remove debris from your area of the lake.

11. CONSULT THE DEPT OF NATURAL RESOURCES BEFORE APPLYING CHEMICAL WEED KILLERS OR HERBICIDES. This is mandatory for all lakes, private and public.

12. DO NOT FEED THE GEESE OR OTHER WATERFOWL. Goose droppings are rich in nutrients and bacteria.

From: Inland Lakes Reference Handbook, Inland Lakes Shoreline Project, Huron River Watershed Council.